Digitized by the Internet Archive
in 2010 with funding from
University of Toronto

http://www.archive.org/details/journalfranklini179fran

T
1
F8
v.179-
180

621369
24 10 55

JOURNAL

OF

THE FRANKLIN INSTITUTE

DEVOTED TO SCIENCE AND THE MECHANIC ARTS

VOL. CLXXIX JANUARY, 1915 No. 1

ARCHITECTURAL ACOUSTICS.*

BY

WALLACE C. SABINE, Sc.D.,

Dean, The Graduate School of Applied Science, Harvard University.

BECAUSE familiarity with the phenomena of sound has so far outstripped the adequate study of the problems involved, many of them have been popularly shrouded in a wholly unnecessary mystery. Of none, perhaps, is this more true than of architectural acoustics. The conditions surrounding the transmission of speech in an enclosed auditorium are complicated, it is true, but are only such as will yield an exact solution in the light of adequate data. It is, in other words, a rational engineering problem.

The problem of architectural acoustics is necessarily complex, and each room presents many conditions which contribute to the result in a greater or less degree, according to circumstances. To take justly into account these varied conditions, the solution of the problem should be quantitative, not merely qualitative; and to reach its highest usefulness and the dignity of an engineering science it should be such that its application can precede, not merely follow, the construction of the building.

In order that hearing may be good in any auditorium it is

---

* Presented Friday evening, October 30, 1914.

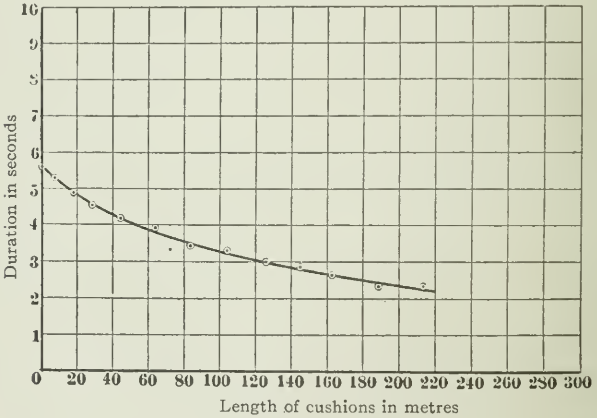
[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

Copyright, 1915, by THE FRANKLIN INSTITUTE.

necessary that the sound should be sufficiently loud, that the simultaneous components of a complex sound should maintain their proper relative intensities, and that the successive sounds in rapidly-moving articulation, either of speech or of music, should be clear and distinct, free from each other and from extraneous noises. These three are the necessary, as they are the entirely sufficient, conditions for good hearing. Scientifically the problem involves three factors: reverberation, interference, and resonance. As an engineering problem it involves the shape of the auditorium, its dimensions, and the materials of which it is composed.

Sound, being energy, once produced in a confined space, will continue until it is either transmitted by the boundary walls or is transformed into some other kind of energy, generally heat. This process of decay is called absorption. Thus, in the lecture-room of Harvard University, in which, and in behalf of which, this investigation was begun, the rate of absorption was so small that a word spoken in an ordinary tone of voice was audible for five and a half seconds afterwards. During this time even a very deliberate speaker would have uttered the twelve or fifteen succeeding syllables. Thus the successive enunciations blended into a loud sound, through which and above which it was necessary to hear and distinguish the orderly progression of the speech. Across the room this could not be done; even near the speaker it could be done only with an effort wearisome in the extreme if long maintained. With an audience filling the room the conditions were not so bad, but still not tolerable. This may be regarded, if one so chooses, as a process of multiple reflection from walls, from ceiling, and from floor, first from one and then another, losing a little at each reflection until ultimately inaudible. This phenomenon will be called reverberation, including, as a special case, the echo. It must be observed, however, that, in general, reverberation results in a mass of sound filling the whole room and incapable of analysis into its distinct reflections. It is thus more difficult to recognize and impossible to locate. The term "echo" will be reserved for that particular case in which a short, sharp sound is distinctly repeated by reflection, either once from a single surface, or several times from two or more surfaces. In the general case of reverberation we are concerned only with the rate of decay of the sound. In the special case of the echo we are concerned not merely with its intensity, but with the interval of time elapsing between the initial sound and the moment it reaches the observer. In the room mentioned as the occasion of this investigation no discrete echo was distinctly perceptible, and the case will serve excellently as an illustration of the more general type of reverberation. After preliminary gropings, first in the literature and then with several optical devices for measuring the intensity of sound, all established methods were abandoned. Instead, the rate of decay was measured by measuring what was inversely proportional to it—the duration of audibility of the reverberation, or, as it will be called here, the duration of audibility of the residual sound. These experiments may be explained to advantage here, for they will give more clearly than would abstract discussion an idea of the nature of reverberation. Broadly considered, there are two, and only two, variables in a room—shape (including size) and materials (including furnishings). In designing an auditorium an architect can give consideration to both; in repair work for bad acoustic conditions it is generally impracticable to change the shape, and only variations in materials and furnishings are allowable. This was, therefore, the line of work in this case. It was evident that, other things being equal, the rate at which the reverberation would disappear was proportional to the rate at which the sound was absorbed. The first work, therefore, was to determine the relative absorbing power of various substances. With an organ pipe as a constant source of sound, and a suitable chronograph for recording, the duration of audibility of a sound after the source had ceased in this room when empty was found to be 5.62 seconds. All the cushions from the seats in Sanders Theatre were then brought over and stored in the lobby. On bringing into the lecture-room a number of cushions, having a total length of 8.2 metres, the duration of audibility fell to 5.33 seconds. On bringing in 17 metres the sound in the room after the organ pipe ceased was audible for but 4.94 seconds. Evidently the cushions were strong absorbents and rapidly improving the room, at least to the extent of diminishing the reverberation. The result was interesting and the process was continued. Little by little the cushions were brought into the room, and each time the duration of audibility was measured. When all the seats (436 in number) were covered, the sound was audible for 2.03 seconds. Then the aisles were covered, and then the platform. Still there were more cushions—almost half as many more. These were brought into the room, a few at a time, as before, and draped on a scaffolding that had been erected around the room, the duration of the sound being recorded each time. Finally, when all the cushions from a theatre seating nearly fifteen hundred persons were placed in the room—covering the seats, the aisles, the platform, the rear wall to the ceiling—the duration of audibility of the residual sound was 1.14 seconds. This experiment, requiring, of course, several nights' work, having been completed, all the cushions were removed and the room was in readiness for the test of other absorbents. It was evident that a standard of comparison had been established. Curtains of chenille, 1.1 metres wide and 17 metres in total length, were draped in the room. The duration of audibility was then 4.51 seconds. Turning to the data that had just been collected, it appeared that this amount of chenille was equivalent to 30 metres of Sanders Theatre cushions. Oriental rugs (Herez, Demirjik, and Hindoostanee) were tested in a similar manner, as were also cretonne cloth, canvas, and hair-felt. Similar experiments, but in a smaller room, determined the absorbing power of a man and of a woman, always by determining the number of running metres of Sanders Theatre cushions that would produce the same effect. This process of comparing two absorbents by actually substituting

Fig. 1.



Curve showing the relation of the duration of the residual sound to the added absorbing material.

one for the other is laborious, and it is given here only to show the first steps in the development of a method. Without going into details, it is sufficient here to say that this method was so perfected as to give not merely relative, but absolute, coefficients of absorption.

In this manner a number of coefficients of absorption were determined for objects and materials which could be brought into and removed from the room, for sounds having a pitch an octave above middle C. In the following table the numerical values are the absolute coefficients of the absorption:

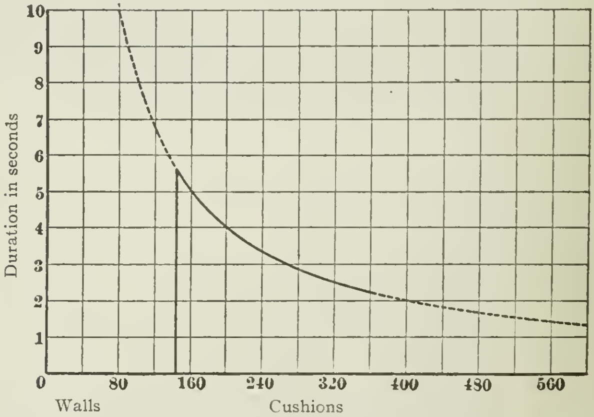
Oil paintings, inclusive of frames	.28
Carpet rugs	.20
Oriental rugs, extra heavy	.29
Cheese-cloth	.019
Cretonne cloth	.15
Shelia curtains	.23
Hair-felt, 2.5 Cm. thick, 8 Cm. from wall	.78
Cork, 2.5 Cm. thick, loose on floor	.16
Linoleum, loose on floor	.12

When the objects are not extended surfaces, such as carpets or rugs, but essentially spacial units, it is not easy to express the absorption as an absolute coefficient. In the following table the absorption of each object is expressed in terms of a square metre of complete absorption:

Audience, per person	.44
Isolated woman	.54
Isolated man	.48
Plain ash settees	.039
Plain ash settees, per single seat	.0077
Plain ash chairs, "bent wood"	.0082
Upholstered settees, hair and leather	1.10
Upholstered settees, per single seat	.28
Upholstered chairs similar in style	.30
Hair cushions, per seat	.21
Elastic-felt cushions, per seat	.20

Of even greater importance was the determination of the coefficient of absorption of floors, ceilings, and wall surfaces. The accomplishment of this called for a very considerable extension of the method adopted. If the reverberation in a room as changed by the addition of absorbing material be plotted, the resulting curve will be found to be a portion of an hyperbola with displaced axes. An example of such a curve, as obtained in the lecture-room of the Fogg Art Museum, in Cambridge, is plotted in the adjacent diagram, Fig. 1. If now the origin of this curve be displaced so that the axes of coördinates are the asymptotes of the rectangular hyperbola, the displacement of the origin measures the initial absorbing power of the room, its floors, walls, and ceilings. Such experiments were carried out in a large number of rooms in which the different component materials entered in very different degrees, and an elimination between these different experiments gave the following coefficient of absorption for different materials:

FIG. 2.



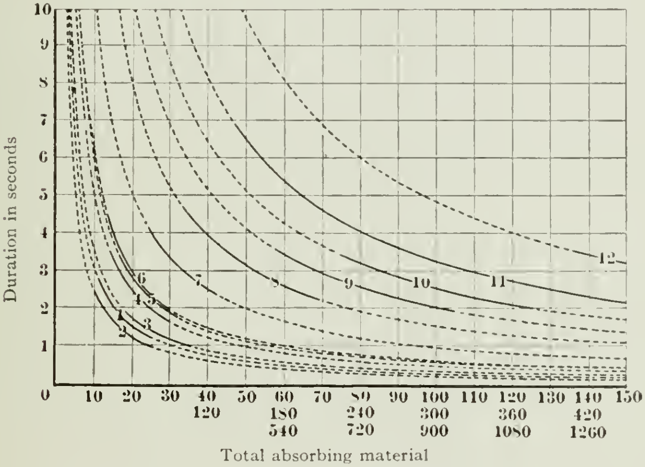
Curve 5 plotted as part of its corresponding rectangular hyperbola. The solid part was determined experimentally; the displacement of this to the right measures the absorbing power of the walls of the room.

Open window	1.000
Wood-sheathing (hard pine)	.061
Plaster on wood-lath	.034
Plaster on wire-lath	.033
Glass, single thickness	.027
Plaster on tile	.025
Brick set in Portland cement	.025

If the experiments in these rooms are plotted in a single diagram, the result is a family of hyperbolæ showing a very interesting relationship to the volumes of the rooms. Indeed, if from these hyperbolas the parameter, which equals the product of the coördinates, be determined, it will be found to be linearly proportional to the volume of the room. These results are plotted in Fig. 4, showing how strict the proportionality is even over a very great range in volume. We have thus at hand a ready method of calculating the reverberation for any room, its volume and the materials of which it is composed being known.

The first five years of the investigation were devoted to violin C, the C an octave above middle C, having a vibration frequency of 512 vibrations per second. This pitch was chosen because, in the art of telephony, it was regarded at that time as the characteristic pitch determining the conditions of articulate speech. The planning of Symphony Hall in Boston forced an extension of this investigation to notes over the whole range of the musical scale, three octaves below and three octaves above violin C.

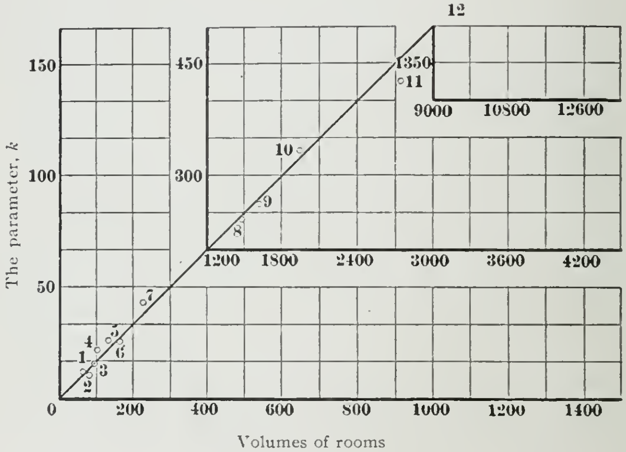
FIG. 3.



The curves of Figs. 8 and 9 entered as parts of their corresponding rectangular hyperbolas. Three scales are employed for the volumes, by groups 1–7, 8–11, and 12.

In the very nature of the problem, the most important datum is the absorption coefficient of an audience, and the determination of this was the first task undertaken. By means of a lecture on one of the recent developments of physics, wireless telegraphy, an audience was thus drawn together and at the end of the lecture requested to remain for the experiment. In this attempt the effort was made to determine the coefficients for the five octaves from $C_2 128$ to $C_6 2048$, including notes E and G in each octave. For several reasons the experiment was not a success. A threatening thunderstorm made the audience a small one, and the sultriness of the atmosphere made open windows necessary, while the attempt to cover so many notes, thirteen in all, prolonged the experiment beyond the endurance of the audience. While this experiment failed, another the following summer was more successful. In the year that had elapsed the necessity of carrying the investigation further than the limits intended became evident, and now the experiment was carried from $C_1 64$ to $C_7 4096$, but included only the C notes, seven notes in all. Moreover, bearing in mind the experiences of the previous summer, it was recognized that even seven notes would come dangerously near overtaxing the patience of the audience. Inasmuch as the coefficient of absorption for $C_4 512$ had already been determined six years before, in the investigations mentioned, the coefficient for this note was not redetermined. The experiment was therefore carried out for the lower three and the upper three notes of the seven. The audience, on the night of this experiment, was much larger than that which came the previous summer, the night was a more comfortable one, and it was possible to close the windows during the experiment. The conditions were thus fairly satisfactory. In

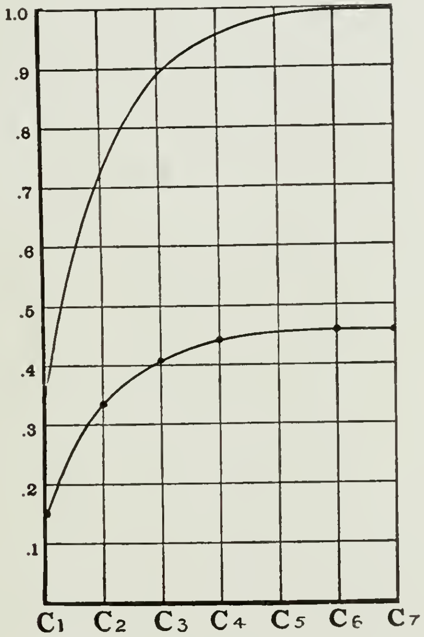
FIG. 4.



The parameters, *k*, plotted against the volumes of the rooms, showing the two proportional.

order to get as much data as possible, and in as short a time, there were nine observers stationed at different points in the room. These observers, whose kindness and skill it is a pleasure to acknowledge, had prepared themselves, by previous practice, for this one experiment. The results of the experiment are shown on the lower curve in Fig. 5. This curve gives the coefficient of absorption per person. It is to be observed that one of the points falls clearly off the smooth curve drawn through the other points. The observations on which this point is based were, however, much disturbed by a street car passing not far from the building, and the departure of this observation from the curve does not indicate a real departure in the coefficient, nor should it cast much doubt on the rest of the work, in view of the circumstances under which it was secured. Counteracting the, perhaps, bad impression which

FIG. 5.

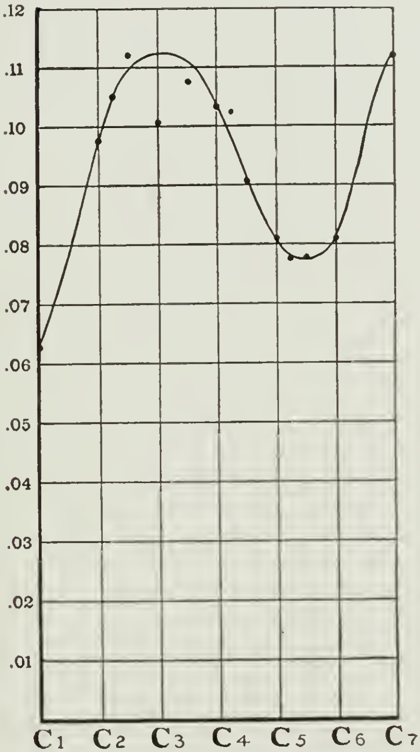


The absorbing power of an audience for different notes. The lower curve represents the absorbing power of an audience per person. The upper curve represents the absorbing power of an audience per square metre as ordinarily seated. The vertical ordinates are expressed in terms of total absorption by a square metre of surface. For the upper curve the ordinates are thus the ordinary coefficients of absorption. The several notes are at octave intervals, as follows: $C_1$64, $C_2$128, C_3 (middle C) 256, $C_4$512, $C_5$1024, $C_6$2048, $C_7$4096.

this point may give, it is a considerable satisfaction to note how accurately the point for C_4512, determined six years before by a different set of observers, falls on the smooth curve through the remaining points. In the audience on which these observations were taken there were 77 women and 105 men. The courtesy of the audience in remaining for the experiment and the really remarkable silence which they maintained are gratefully acknowledged.

The next experiment was on the determination of the absorption of sound by wood sheathing. It is not an easy matter to find conditions suitable for this experiment. The room in which the absorption by wood sheathing was determined in the earlier experiments was not available for these. It was available then only because the building was new and empty. When these more elaborate experiments were under way the room became occupied, and in a manner that did not admit of its being cleared. Quite a little searching in the neighborhood of Boston failed to discover an entirely suitable room. The best one available adjoined a night lunch-room. The night lunch was bought out for a couple of nights, and the experiment was tried. The work of both nights was much disturbed. The traffic past the building did not stop until nearly two o'clock, and began again at four. The interest of those passing on foot throughout the night, and the necessity of repeated explanations to the police, greatly interfered with the work. This detailed statement of the conditions under which the experiment was tried is made by way of explanation of the irregularity of the observations recorded on the curve, and of the failure to carry this particular line of work further. The first night seven points were obtained for the seven notes C_164 to C_74096. The reduction of these results on the following day showed variations indicative of maxima and minima, which, to be accurately located, would require the determination of intermediate points. In the experiment the following night points were determined for the E and G notes in each octave between C_2128 and C_62048. Other points would have been determined, but time did not permit. It is obvious that the intermediate points in the lower and in the higher octave were desirable, but no pipes were to be had on such short notice for this part of the range, and in their absence the data could not be obtained. In the diagram, Fig. 6, the points lying on the vertical lines were determined the first night. The points lying between the vertical lines were determined the second night. The accuracy with which these points fall on a smooth curve is, perhaps, all that could be expected in view of the difficulty under which the observations were conducted and the limited time available. One point in particular

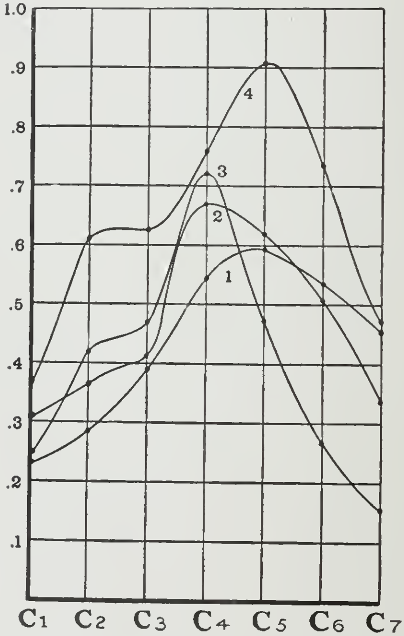
FIG. 6.



The absorbing power of wood sheathing, two centimetres thick, North Carolina pine. The observations were made under very unsuitable conditions. The absorption is here due almost wholly to yielding of the sheathing as a whole, the surface being shellacked, smooth, and non-porous. The curve shows one point of resonance within the range tested, and the probability of another point of resonance above. It is not possible now to learn as much in regard to the framing and arrangement of the studding in the particular room tested as is desirable. C_3 (middle C) 256.

falls far off from this curve, the point for $C_3$256, by an amount which is, to say the least, serious, and which can be justified only by the conditions under which the work was done. The general trend of the curve seems, however, established beyond reasonable doubt. It is interesting to note that there is one point of maximum absorption, which is due to resonance between the walls and the sound, and that this point of maximum absorption lies in the lower part, though not in the lowest part, of the range of pitch tested. It would have been interesting to determine, had the time and facilities permitted, the shape of the curve beyond $C_7$4096, and to see if it rises indefinitely, or shows, as is far more likely, a succession of maxima.

FIG. 7.

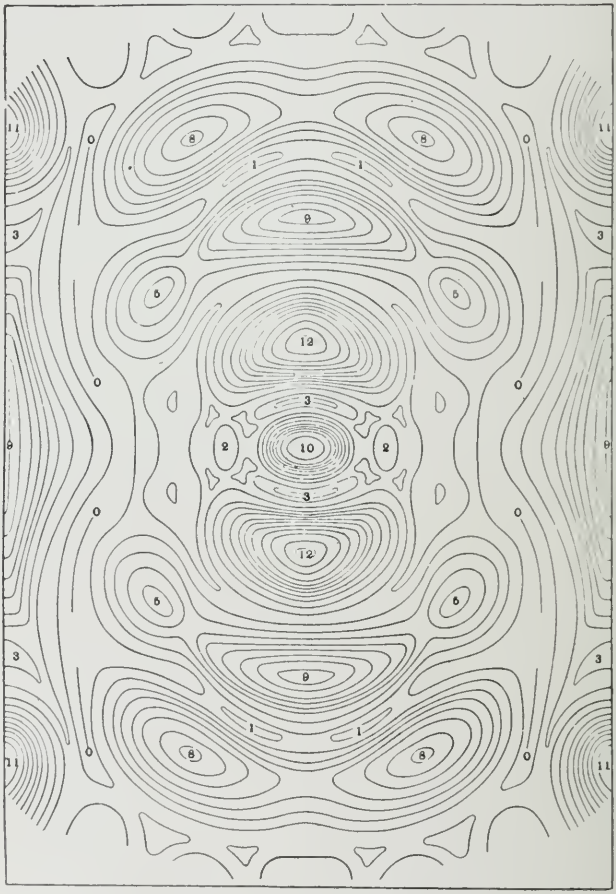


The absorbing power of cushions. Curve 1 is for "Sanders Theatre" cushions of wiry vegetable fibre, covered with canvas ticking and a thin cloth. Curve 2 is for "Brooks House" cushions of long hair, covered with the same kind of ticking and plush. Curve 3 is for "Appleton Chapel" cushions of hair, covered with ticking and a thin leatherette. Curve 4 is for the elastic felt cushions of commerce, of elastic cotton, covered with ticking and short nap plush. The absorbing power is per square metre of surface. C_3 (middle C) 256.

The experiment was then directed to the determination of the absorption of sound by cushions, and for this purpose return was made to the constant temperature room. Working in the manner indicated in the earlier papers for substances which could be carried in and out of a room, the curves represented in Fig. 7 were obtained. Curve 1 shows the absorption coefficient for the Sanders Theatre cushions, with which the whole investigation was begun ten years ago. These cushions were of a particularly open grade of packing, a sort of wiry grass or vegetable fibre. They were covered with canvas ticking, and that, in turn, with a very thin cloth covering. Curve 2 is for cushions borrowed from the Phillips Brooks House. They were of a high grade, filled with long, curly hair, and covered with canvas ticking, which was, in turn, covered by a long nap plush. Curve 3 is for the cushion of Appleton Chapel, hair covered with a leatherette, and showing a sharper maximum and a more rapid diminution in absorption for the higher frequencies, as would be expected under such conditions. Curve 4 is probably the most interesting, because for more standard commercial conditions ordinarily used in churches. It is to be observed that all four curves fall off for the higher frequencies, all show a maximum located within an octave, and three of the curves show a curious hump in the second octave. This break in the curve is a genuine phenomenon, as it was tested time after time. It is perhaps due to a secondary resonance, and it is to be observed that it is the more pronounced in those curves that have the sharper resonance in their principal maxima.

In both articulate speech and in music the source of sound is rapidly and, in general, abruptly changing in pitch, quality, and loudness. In music one pitch is held during the length of a note. In articulate speech the unit or element of constancy is the syllable. Indeed, in speech it is even less than the length of a syllable, for the open vowel sound which forms the body of a syllable usually has a consonantal opening and closing. During the constancy of an element, either of music or of speech, a train of sound waves spreads spherically from the source, just as a train of circular waves spreads outward from a rocking boat on the surface of still water. Different portions of this train of spherical waves strike different surfaces of the auditorium and are reflected. After such reflection they begin to cross each other's paths. If their paths are so different in length that one train of waves has entirely passed before the other arrives at a particular point, the only phenomenon at that point is prolongation of the sound. If the space between the two trains of waves be sufficiently great, the effect will be that of an echo. If there be a number of such trains of waves thus widely spaced, the effect will be that of multiple echoes. On the other hand, if two trains of waves have travelled so nearly equal paths that they overlap, they will, dependent on the difference in length of the paths which they had travelled, either reinforce or mutually destroy each other. Just as two equal trains of water waves crossing each other may entirely neutralize each other if the crest of one and the trough of the other arrive together, so two sounds, coming from the same source, in crossing each other may produce silence. This phenomenon is called interference, and is a common phenomenon in all types of wave motion. Of course, this phenomenon has its

FIG. 8.



Distribution of intensity on the head level in a room with a barrel-shaped ceiling, with centre of curvature on the floor level.

complement. If the two trains of water waves so cross that the crest of one coincides with the crest of the other and trough with trough, the effects will be added together. If the two sound waves be similarly retarded, the one on the other, their effects will also be added. If the two trains of waves be equal in intensity, the combined intensity will be quadruple that of either of the trains separately, as above explained, or zero, depending on their relative retardation. The effect of this phenomenon is to produce regions in an auditorium of loudness and regions of comparative or even complete silence. It is a partial explanation of the so-called deaf regions in an auditorium.

It is not difficult to observe this phenomenon directly. It is difficult, however, to measure and record the phenomenon in such a manner as to permit of an accurate chart of the result. Without going into the details of the method employed, the result of these measurements for a room very similar to the Congregational Church in Naugatuck, Connecticut, is shown in the accompanying chart. The room experimented in was a simple, rectangular room with plain side walls and ends and with a barrel or cylindrical ceiling. The result is clearly represented in Fig. 8, in which the intensity of the sound has been indicated by contour lines in the manner employed in the drawing of the geodetic survey maps. The phenomenon indicated in these diagrams was not ephemeral, but was constant so long as the source of sound continued, and repeated itself with almost perfect accuracy day after day. Nor was the phenomenon one which could be observed merely instrumentally. To an observer moving about in the room it was quite as striking a phenomenon as the diagrams suggest. At the points in the room indicated as high maxima of intensity in the diagram the sound was so loud as to be disagreeable, at other points so low as to be scarcely audible. It should be added that this distribution of intensity is with the source of sound at the centre of the room. Had the source of sound been at one end and on the axis of the cylindrical ceiling, the distribution of intensity would still have been bilaterally symmetrical, but not symmetrical about the transverse axis.

When a source of sound is maintained constant for a sufficiently long time, a few seconds will ordinarily suffice: the sound becomes steady at every point in the room. The distribution of the intensity of sound under these conditions is called the inter-

FIG. 9.

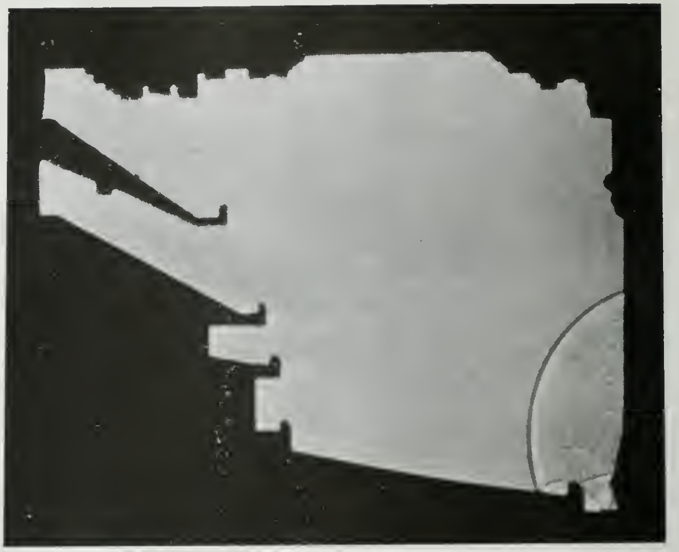


FIG. 10.

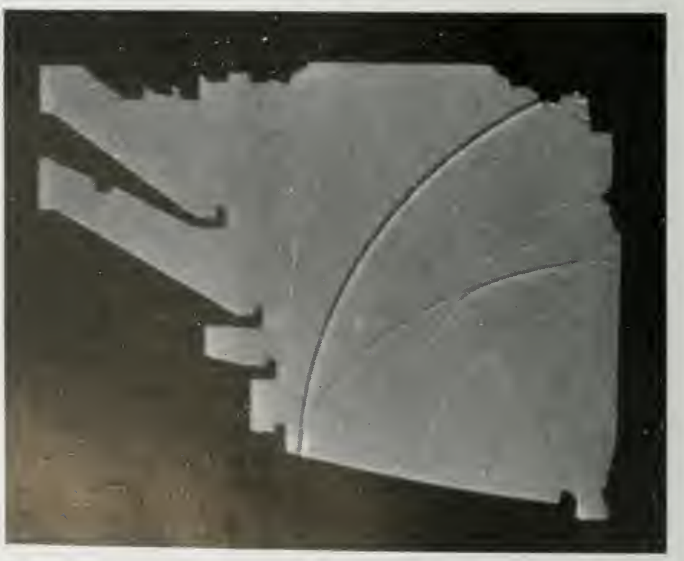


FIG. 11.

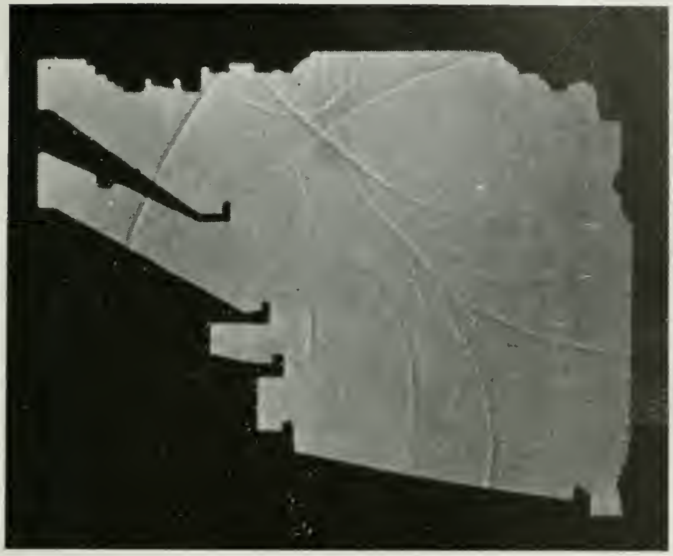


FIG. 12.

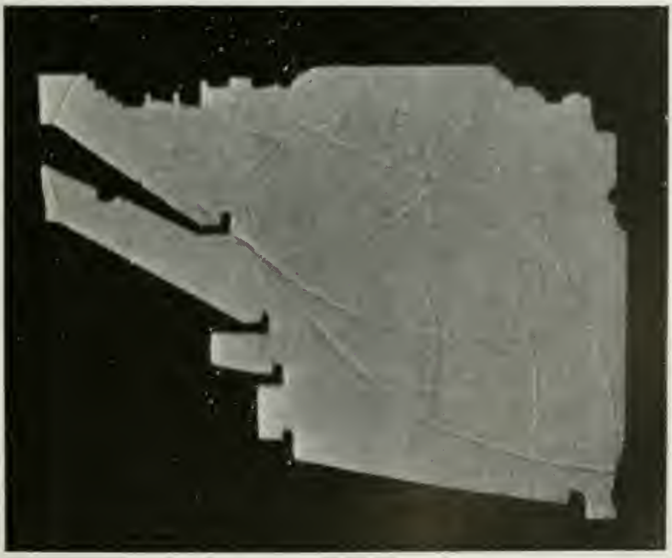


FIG. 13.

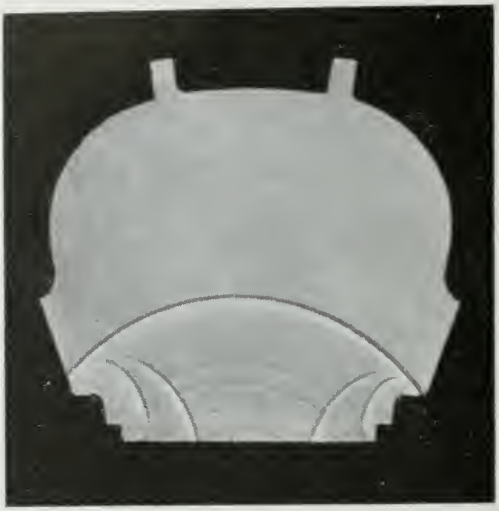
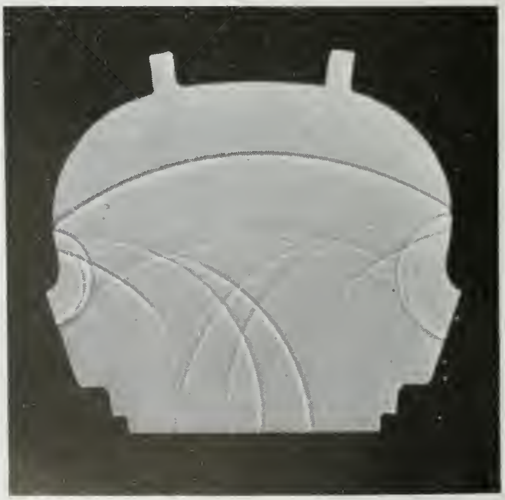


FIG. 14.



ference system, for that particular note, of the room or space in question. If the source of sound is suddenly stopped, it requires some time for the sound in the room to be absorbed. This pro-

FIG. 15.

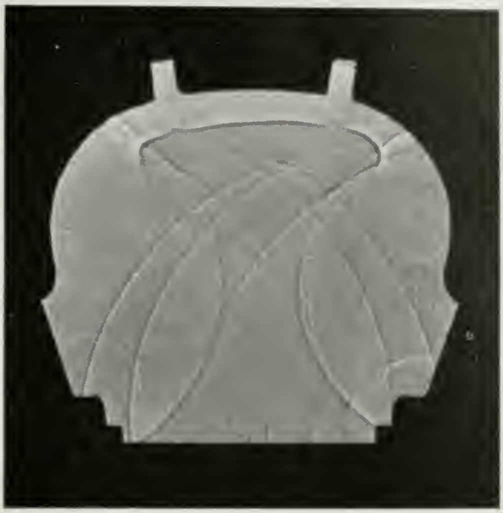
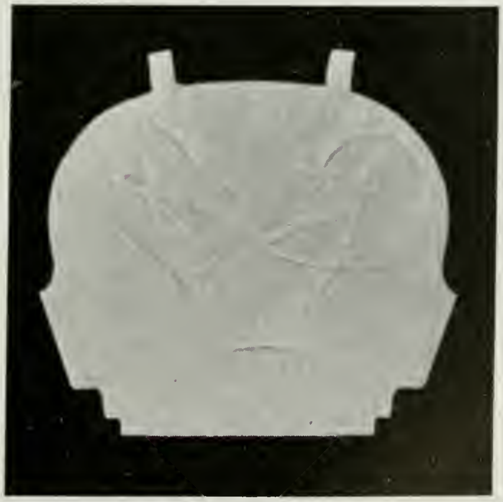


FIG. 16.



longation of sound after the source has ceased is called reverberation. If the source of sound, instead of being maintained, is short and sharp, it travels as a discrete wave or group of waves about the room, reflected from wall to wall, producing echoes. In the Greek theatre there was ordinarily but one echo, "doubling the case ending," while in the modern auditorium there are many, generally arriving at a less interval of time after the direct sound and therefore less distinguishable, but stronger and therefore more disturbing.

The formation and the propagation of echoes may be admirably studied by an adaptation of the so-called *schlieren-Methode* device for photographing air disturbances. It is sufficient here to say that the adaptation of this method to the problem in hand consists in the construction of a model of the auditorium to be studied to proper scale, and investigating the propagation through it of a proportionally scaled sound wave. To examine the formation of echoes in a vertical section, the sides of a model are taken off and, as the sound is passing through it, it is illuminated instantaneously by the light from a very fine and somewhat distant electric spark. In the accompanying illustrations, reduced from the photographs, the enframing silhouettes are shadows cast by the model, and all within are direct photographs of the actual sound wave and its echoes. The four photographs show the sound and its echoes at different stages in their propagation through the room, the particular auditorium under investigation being the New Theatre in New York. It is not difficult to identify the master wave and the various echoes which it generates, nor, knowing the velocity of sound, to compute the interval at which the echo is heard.

To show the generation of echoes and their propagation in a horizontal plane, the ceiling and floor of the model are removed and the photograph taken in a vertical direction. The photographs shown in Figs. 13 to 16 show the echoes produced in the horizontal plane passing through the marble parapet in front of the box.

While these several factors, reverberation, interference, and echo, in an auditorium at all complicated are themselves complicated, nevertheless they are capable of an exact solution, or, at least, of a solution as accurate as are the architect's plans in actual construction. And it is entirely possible to calculate in advance of construction whether or not an auditorium will be good, and, if not, to determine the factors contributing to its poor acoustics and a method for their correction.

AIR-GAP FLUX DISTRIBUTION IN DYNAMO-ELECTRIC GENERATORS.*

BY

ALFRED STILL,

Purdue University, Indiana.

An experienced designer may go far and obtain good results without resorting to the more or less tedious process of plotting flux distribution curves; but occasions arise when his experience and judgment fail him, and when a reasonably accurate method of predetermining the distribution of flux density over the surface of the armature would give him all necessary information. A method of designing electric machinery—whether continuous-current dynamos or alternating-current generators—which involves the plotting of the flux distribution curves, has much to recommend it, not only to the student, but also to the professional designer. The advantage from the student's and teacher's point of view is that a more real and accurate conception of the operating conditions can be obtained than by using empirical formulas, or making the unscientific assumptions which are otherwise necessary. The designer will be glad to avail himself of a practical method of plotting flux curves when departures have to be made from standard models, or when it is desired to investigate thoroughly the effects of cross-magnetization upon commutation or pressure regulation.

The procedure about to be described is based upon the early work of Professor W. E. Goldsborough,[1] and is a modification of the method outlined by Professor Charles R. Moore in his paper on "Air-Gap Flux Distribution in Direct-Current Machines."[2] It is followed by the students of the School of Electrical Engineering, Purdue University, in the courses of Electrical Design, and it has been found to give results agreeing very

---

* Communicated by the Author.

[1] *Transactions A. I. E. E.*, vol. 15, p. 515; vol. 16, p. 461, and vol. 17, p. 679.

[2] *Transactions A. I. E. E.*, vol. 31, p. 509.

closely with experimental measurements made on a number of commercial machines. The method—which is capable of still further elaboration—will be explained as briefly as possible; but the ground cannot be covered adequately without dwelling on a few points that have been discussed in some detail by the writers previously referred to. The present writer's chief claim to originality lies in the method of deriving the curves giving the distribution of M.M.F. over the armature surface, which he believes to be new. It is usual to make more or less reasonable guesses as to the probable resultant M.M.F. at the various points on the armature surface when the demagnetizing influence of adjacent poles is taken into account, and this sometimes leads to unreliable conclusions.

The method proposed by Professor Goldsborough for predetermining the distribution of flux density over the armature surface assumes a smooth-core armature. It is true that he also considers the case of slotted armatures, but the application of his method to any but smooth cores involves so many measurements and detailed computations as to render it unpractical. If a method is to be of real practical utility it must include the common case of the slotted armature, and the writer believes that the Goldsborough method in its simplest form may conveniently be used if the slotted armature is replaced by an imaginary smooth-core armature of the proper "equivalent" diameter. It will, therefore, be well to consider, in the first place, what is to be understood by the equivalent air-gap.

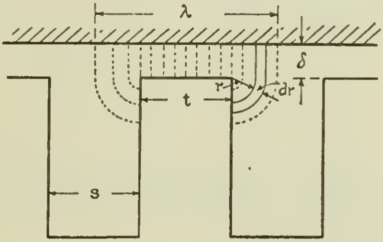
AIR-GAP FLUX DISTRIBUTION WITH TOOTHED ARMATURES.

The determination of the flux densities in all parts of the tooth and slot for various values of the average air-gap flux density is so difficult and complicated a problem that it is safe to say no correct mathematical solution may be looked for, although empirical rules and formulas of great practical value may serve the purpose of the designer.

The reluctance of the magnetic paths between pole face and armature core can be calculated with but little error for the two extreme cases of very low and very high average flux density over the tooth pitch; but for intermediate values the designer has still to rely on his judgment, based on familiarity with the laws of the magnetic circuit.

To calculate the permeance of the air paths over one slot pitch at the centre of the pole face, when the density is low, the magnetic lines are supposed to follow the paths indicated in Fig. 1. The tooth is drawn, for convenience, with parallel sides, and the magnetic lines entering the sides of the tooth are supposed to follow a path consisting of a straight portion of length δ, equal to the actual clearance, and a circular arc of radius r, all as indicated in the figure. This is obviously an arbitrary assumption, but it is convenient for calculation and gives very good results. It agrees very closely with the results obtained by Messrs. H. S. Hele-Shaw, Alfred Hay, and P. H. Powell in their classic Institution paper,[3] and also with the *correct* mathematical conclusions arrived at by Mr. F. W. Carter,[4] based on certain assumptions, including that of infinite permeability of the iron in the teeth.

FIG. 1.



Considering a portion of the air-gap one centimetre long axially (*i.e.*, in a direction normal to the plane of the section shown in Fig. 1.), the permeance over the slot pitch of width λ is seen to be made up of two parts: (1) the permeance P_1 between pole face and top of tooth, of value $P_1=\frac{t}{\delta}$, and (2) the permeance $2\,P_2$ where P_2 is the permeance between the pole face and one side of the tooth. Consider any small section of thickness

---

[3] "Hydrodynamical and Electromagnetic Investigations Regarding the Magnetic-flux Distribution in Toothed-core Armatures," *Proc. Inst. E. E.*, vol. 34, p. 21.

[4] *Electrical World*, vol. 38, Nov. 30, 1901, p. 884.

dr as indicated in Fig. 1. The permeance of such a path, of depth one centimetre measured axially, is

$$dP_2 = \frac{dr}{\delta + \frac{\pi}{2} r}$$

$$= \frac{2}{\pi} \times \frac{dr}{\left(\frac{2\delta}{\pi}\right) + r}$$

and

$$P_2 = \frac{2}{\pi} \int_0^{\frac{s}{2}} \frac{dr}{\frac{2\delta}{\pi} + r}$$

$$= \frac{2}{\pi} \log_\epsilon \frac{\delta + \frac{\pi s}{4}}{\delta}$$

The average permeance *per square centimetre* over the slot pitch at centre of pole is, therefore,

$$P_{sq.\,cm.} = \frac{\frac{t}{\delta} + \frac{4}{\pi} \log_\epsilon \frac{\left(\delta + \frac{\pi s}{4}\right)}{\delta}}{t+s} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The reciprocal of this quantity is the reluctance per square centimetre of cross-section, or the equivalent air-gap length δ_e. The required expression is, therefore:

$$\delta_e = \frac{t+s}{\frac{t}{\delta} + \frac{4}{\pi} \log_\epsilon \left(\frac{\pi s}{4\delta} + 1\right)} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)^5$$

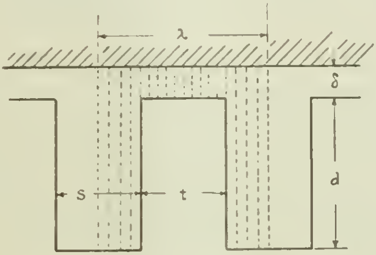
Consider now Fig. 2, which illustrates the case of a highly saturated tooth. The lines of flux are shown parallel over the whole of the slot pitch, a condition which is approached—but never attained—as the density in the tooth is forced up to higher and higher values. It is obviously only when the permeability of the iron in the tooth becomes equal to unity—that is to say, equal to the permeability of the air paths—that this parallelism of the flux lines would occur, and the equivalent air-gap would be $\delta_e = \delta$, to which would have to be added another air-gap of

---

[5] If the ventilating ducts are closely spaced, or exceptionally wide, the gap, δ_e, for the equivalent smooth-core armature, as given by formula (2), might have to be slightly modified; but the calculation of fringing at the sides of vent ducts is usually an unnecessary refinement.

length d to represent the reluctance of the teeth and slots. This is an extreme, and indeed an impossible, condition; but, since the actual distribution of the lines of flux in tooth and slot cannot be predetermined, the calculations for very high densities are usually made by assuming the flux lines to be parallel, as indicated in Fig. 2. It is when this assumption is made for low values of the density that errors are likely to be introduced. The following method of calculating the joint reluctance of tooth and slot should not be used for tooth densities below 20,000 gausses

FIG. 2.



Considering one centimetre only of axial net length of armature core (*i.e.*, 1 cm. total thickness of iron), the reluctance of the air-gap and tooth, taken over the width of one tooth only, is,

$$R_1 = \frac{\delta}{t} + \frac{d}{\mu t} = \frac{(d+\mu\delta)}{\mu t}$$

The reluctance of the slot portion of the total tooth pitch is,

$$R_2 = \frac{(d+\delta)}{s}$$

The air-gap of the equivalent smooth-core armature—being the reluctance per square centimetre—is, therefore,

$$\delta_e = \frac{(t+s)}{\frac{1}{R_1} + \frac{1}{R_2}}$$

which can be put in the form,

$$\delta_e = \frac{(t+s)(d+\delta)}{\mu t\left(\frac{d+\delta}{d+\mu\delta}\right) + s} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

This equivalent air-gap includes the reluctance of the tooth itself when the flux density is high. It is seen to depend upon the permeability of the iron, and, therefore, upon the actual flux density in the tooth. In order to make use of formula (3), a value for the flux density in the tooth must be assumed. A method of working which involves a change in the equivalent air-gap for various values of the flux density would be unpractical, and, since no exact method is ever likely to be developed, some sort of compromise must be made. It is convenient to think of the reluctance of air-gap, teeth, and slots as consisting of two reluctances in series, (*a*) the reluctance of the equivalent air-gap (as calculated by formula (2) for the centre of the pole face), and (*b*) the reluctance of the tooth. The calculation of this latter quantity depends upon a knowledge of the actual flux density in the tooth. For low densities in the iron—up to about 20,000 gausses—the actual tooth density will be approximately equal to the apparent density; that is to say, practically all the flux entering the armature over one tooth pitch will pass into the core through the root of the tooth. For densities exceeding 20,000 gausses, a closer estimate of the correct value of the tooth density may be made by assuming the condition of Fig. 2.

Let the meaning of the symbols be as follows:

B_g = the average air-gap density at armature surface; *i.e.*, the average density over one tooth pitch of width $\lambda = t + s$.
B_t = the actual tooth density.
B_s = the density in the slot.

Then, on the asumption that the lines of flux are truly parallel, the total flux over net axial length of one centimetre may be written,

$$\phi_\lambda = (t+s)B_g \qquad (4)$$

or

$$\phi_\lambda = tB_t + sB_s \qquad (5)$$

It is possible to express B_g in terms of B_t and other known quantities, because the M.M.F. required to overcome the reluctance of air-gap proper and tooth is the same as that required to overcome the reluctance of air-gap proper and slot, seeing that these paths are in parallel between what may be considered equipotential surfaces; thus,

$$B_s(d+\delta) = B_t\left(\frac{d}{\mu} + \delta\right)$$

and

$$B_s = B_t \frac{d+\mu\delta}{\mu(d+\delta)}$$

By substituting this value of B_s in formula (5), and equating (4) and (5), the relation between tooth density and average air-gap density is obtained. This relation is,

$$B_g = B_t \frac{t + \frac{(d+\mu\delta)s}{\mu(d+\delta)}}{(t+s)} \quad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

By assuming values of B_t ranging between 20,000 and (say) 26,000 gausses, the corresponding values of B_g can be calculated by formula (6), and a curve plotted from which values of B_t can be found when B_g is known.

CORRECTION FOR TAPER OF TOOTH.

The assumption of parallel sides to the tooth is justified only when the diameter of the armature is large relatively to the slot pitch. The dimension t in formula (6) should, in the first place, be the width of the narrowest part of the tooth, as it is important that the density at this point be known; it rarely exceeds 24,000 gausses in continuous-current machines, and is less in alternators. When the field system revolves, as in most modern alternators, the armature teeth will usually be wider at the root than at the top, and but little error will be introduced by taking for t the average width, for the purpose of calculating the average density B_t and the ampère-turns required for the teeth. It may further be mentioned that, since the tooth density rarely exceeds 20,000 lines per square centimetre in alternating-current machines, the formula (6) is not applicable. The assumption then made is that the whole of the flux over one slot pitch passes through the iron of the tooth; which leads to the relation

$$B_t = B_g \frac{(t+s)}{t} \frac{L_g}{L_n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

where L_g and L_n stand respectively for the gross and net lengths of the armature core.

The case of a tooth with considerable taper, in which the density at root is in excess of 10,000 gausses, may be dealt with by the application of Simpson's rule. Having determined the density B_t at the root of the tooth, by applying formula (6) or (7) as the case may demand, the assumption is then made that the total flux in the tooth remains unaltered through other parallel sections.[6]

The value of the magnetizing force H (or the ampère-turns required per unit length) can then be determined for any section of the tooth by referring to the B–H curves for the iron used in the armature. It is sufficient to determine H for three sections only.

Let these values be:

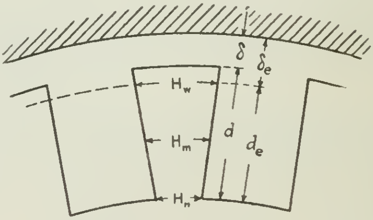
H_n at narrowest section
H_w at widest section
H_m at centre (*i.e.*, where the value of B_m is $\frac{B_n+B_w}{2}$)

Then, if the portion of B–H curve involved is supposed to be a parabola, Simpson's approximation is,

Average $H=\frac{1}{6}H_n+\frac{2}{3}H_m+\frac{1}{6}H_w$ . . . . (8)

Referring to Fig. 3, it will be seen that H_w is taken at the section which would be the top of the tooth if the air-gap were increased from δ to the "equivalent" value δ_e as calculated by formula (2). This is recommended as a good practical compromise; and the M.M.F. in gilberts required to overcome the reluctance of the tooth is $H \times d_e$ where d_e, the equivalent length of tooth, must be expressed in centimetres. If preferred, the formula (8) can be modified to give an average value of the necessary ampère-turns per inch.

FIG. 3.



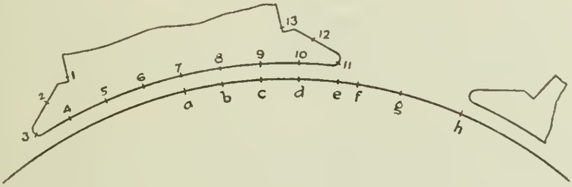
---

[6] This is not a correct assumption when the root density is very high, because in that case flux will leak out from the sides of the tooth to the bottom of the slot; and at some distance from the bottom of slot (the taper being as indicated in Fig. 3) the total flux in the tooth will be greater than at the root cross-section.

VARIATION OF PERMEANCE OVER POLE PITCH.

The permeance per square centimetre of the air-gap when the armature is slotted may be calculated *for the centre of the pole face,* by using formula (1). This value will not change appreciably for other points under the pole shoe if the bore of the field magnets is concentric with the armature; but near the pole tips, and in the interpolar space, it will decrease at a more or less rapid rate, depending on the geometric configuration of the pole pieces, and their circumferential width relatively to pole pitch and air-gap length. Professor Goldsborough, in the series of papers previously referred to, considers a narrow section normal to the shaft through pole and armature; he then makes certain assumptions which cannot reasonably be disputed, and derives a curve showing the distribution of flux density over the surface of the armature. The method about to be explained is based on this work of Professor Goldsborough, as modified and elaborated by Professor C. R. Moore. Let the pole shoe in Fig. 4 be thought of as unaffected by the neighboring poles. It tends to send flux into the armature; and if the very reasonable assumption is made that the pole shoe is an equipotential surface, the density of the flux entering the armature will, at every point on the armature periphery, be proportional to the permeance between that point and the surface of the pole shoe as shown in the figure. The assumption is that, whatever may be the M.M.F. tending to send flux from the point *a* on armature to the point 7 on pole (see Fig. 4), the same M.M.F. tends to send flux between any other two points, such as *a* – 10 or *d* – 2.

FIG. 4.



Set out a number of *equally spaced* points on the pole shoe, and consider each one as the centre of a small surface from which flux tends to go to any given point on the armature, such as *d*, considered also as the centre of a small surface. The drop of potential along a line such as $d-7$ is assumed the same as that along any other line, such as $d-12$,[7] and the magnetic force at d due to the small surface 7 is $\frac{\text{M.M.F.}}{\text{length } (d-7)}$, while the magnetic force due to the small surface 12 is $\frac{\text{M.M.F.}}{\text{length } (d-12)}$; that is to say, it is proportional to the *reciprocal* of the distance between the points considered.[8]

The method of procedure may be summed up as follows:

Draw to any convenient scale a section through one pole shoe and the armature core, making the diameter of the latter such that the clearance at the centre is the equivalent air-gap δ_e as calculated by formula (2). Set off a number of equally spaced points on the pole shoe surface, and a number of points (not necessarily equally spaced) on the armature surface.[9] Measure the length of the shortest air path between any one point on the armature and *all* the points on the pole face. Take the sum of the reciprocals of these lengths, and repeat the process for all the other points on the armature.[10] The numbers so obtained are proportional to the flux density over the armature surface at the point considered. By setting out the points *a, b, c,* etc., on a straight line representing a "developed" armature periphery, and plotting as ordinates the figures obtained by the summation of reciprocals, a curve such as Fig. 5 is obtained. This is a graphic representation of the flux distribution over armature surface if the one pole is considered as acting alone, the other poles being so far removed that they have no influence on this distribution.

For a given value of the M.M.F. this curve could be plotted in terms of the gausses, or lines per square centimetre, entering the armature at any point on the surface. But,

---

[7] Measured as the shortest distance in air, *not* through the iron of the pole shoe.

[8] The law of squares does not apply here, because the section considered involves the idea of other parallel sections on each side, the effect of which is to keep all the flux lines within the section, *i.e.*, in the plane of the paper on which Fig. 4 is drawn.

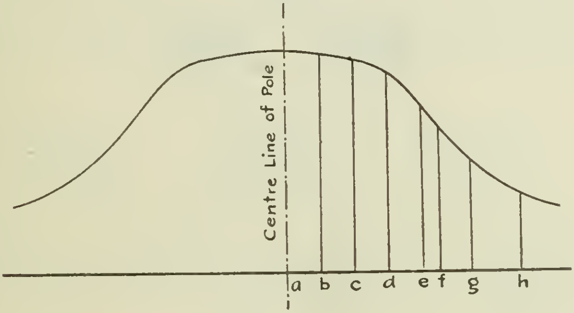
[9] A distribution of armature points as indicated on Fig. 4 will give good results. The points *a, b, c, d,* and *e* should be chosen immediately below the corresponding points on the pole; otherwise, when the measurements are taken, the shortest distance from pole face to armature—which it is important to know—would not be included.

[10] On account of symmetry, it is not necessary to take armature points on both sides of the centre line.

Flux per square centimetre $= B = M.M.F. \times$ Permeance per sq. cm.,

from which it is seen that the curve can be calibrated to indicate the permeance per square centimetre of armature surface between any point on the armature surface and the pole shoe considered as an equipotential surface. The ordinates of the curve as drawn are of arbitrary height, depending upon the scale used in taking the measurements; but, since a value for permeance per square centimetre may be calculated by formula (1) for the centre of the pole, it is an easy matter to provide a scale for Fig. 5 by which the air-gap permeance per square centimetre can be read for any point on the armature circumference.

FIG. 5.



EFFECT OF NEIGHBORING POLES.

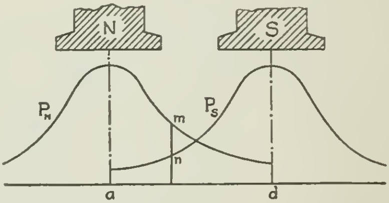
In Fig. 6 the N and S poles are shown close together, as they would be in an actual machine. They are supposed to be excited with the same number of ampère-turns. The permeance curve for the pole N is marked P_N, while an exactly similar curve for pole S is marked P_S. Each of these curves would also represent the flux distribution over armature surface if the corresponding pole were acting alone. As it is, the magnetic force, and therefore the flux density, at the point *d* will be the difference between a number of magnetic lines from the pole N, proportional to the ordinate *dm*, and a number of magnetic lines from the pole S, proportional to the ordinate *dn;* or, in general terms,

$$B = (M.M.F.) \times (P_N - P_S)$$

where $(M.M.F.)$ is 0.4π times the ampère-turns on one pole.

The flux actually passing from the pole N into one square centimetre of the armature surface at the point d will no longer be dm, but $(dm - dn)$; and this suggests a convenient way of working which involves the idea of a *resultant M.M.F.* tending to send flux to any *one pole* from any point on the armature surface. The armature points considered must obviously lie within the limits of the pole pitch as measured between two neutral zones on the armature surface. By neutral zone is meant, not the geometric neutral, or point midway between two poles, but the zone where the flux neither enters nor leaves the armature: its position varies with the load and power factor in alternating-current machines, and with load and brush position in direct-current machines.

FIG. 6.



Let $(M.M.F.)$ = the ampère-turns on any one pole,

$(M.M.F.)_d$ = the resultant M.M.F. due to field excitation, the point d,

B_d = the average flux density (gausses) in air-gap at point d of armature surface,

P_{Nd} = the permeance, armature to pole N, at point d,

P_{Sd} = the permeance, armature to pole S, at point d,

then

$$B_d = (M.M.F.)_d \times P_{Nd} = (M.M.F.) \times (P_{Nd} - P_{Sd})$$

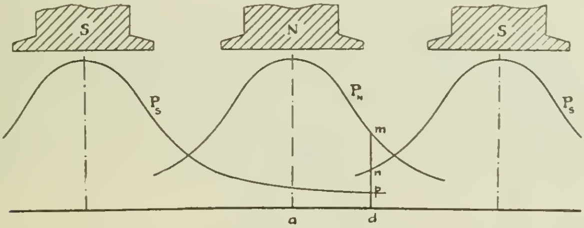
and

$$(M.M.F.)_d = (M.M.F.) \times \frac{P_{Nd} - P_{Sd}}{P_{Nd}} \quad \ldots\ldots\ldots\ldots (9)$$

In this manner a curve of resultant M.M.F. for open-circuit conditions can be drawn, provided the shape of pole shoe and length of air-gap have previously been decided upon, and the permeance curve plotted. It may be mentioned that, although two poles only have been shown in Fig. 6, the demagnetizing effect of the poles on both sides of the pole considered should be taken into account. This leads to Fig. 7, from which it will be seen that the quantity P_{Sd} in formula (9) should actually be $(dn + dp)$. The influence of poles still farther removed is inappreciable, and need not be considered. It is, in fact, doubtful whether or not the correction for demagnetizing action of neighboring poles is of much value for points other than those in the interpolar space, because it is difficult to allow for the shading effect of the iron pole shoes. In other words, the height of the ordinate dp of Fig. 7 (which is in any case very small) cannot be accurately determined.

In the case of high-speed generators of the revolving field type with distributed winding the pole pitch is usually large, and the influence of adjacent poles is small. A different method of procedure for obtaining the open-circuit M.M.F. curve is then to be preferred; but this will be explained later, in order that the development of the problem under consideration shall not be delayed.

FIG. 7.



OPEN-CIRCUIT FLUX DISTRIBUTION CURVES AS INFLUENCED BY TOOTH SATURATION.

Before considering the effect of the armature current in altering the distribution of magnetizing force over the armature periphery, it seems desirable to examine briefly how the degree of saturation of the teeth may be taken into account, and a correct flux distribution curve plotted. The method about to be explained is due to Professor C. R. Moore: it is probably more easily applied and less tedious than an equally scientific method more recently proposed by Dr. Alfred Hay.[11] If it is understood that the permeance curve as shown in Fig. 5 has been drawn and calibrated to read air-gap permeance per square centimetre of armature surface, it follows that, for a given value of M.M.F. between pole and armature, the flux density at any point—as for instance d—will be

---

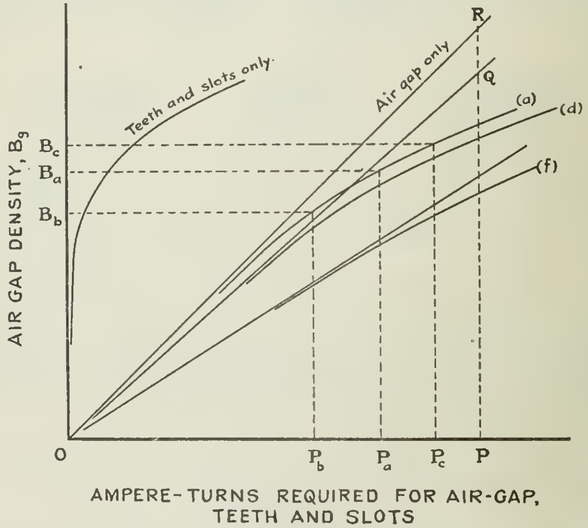
[11] "Predetermining Field Distortion in Continuous-current Generators," A. Hay, *Electrician,* 72, pp. 283–285, Nov. 21, 1913.

$$B_d = (\text{M.M.F.})_d \times \text{value of ordinate of Fig. 5 at } d,$$

but in order to get the flux into the armature core the reluctance of the teeth must be considered.

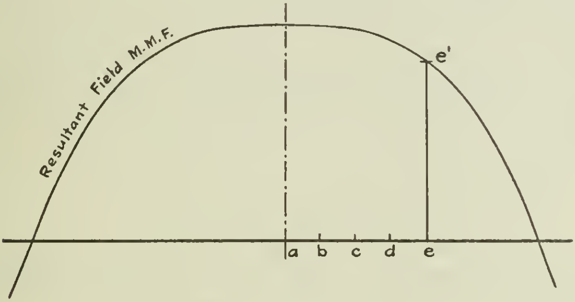
For any value of the air-gap density B_g there is a corresponding value of the tooth density, B_t, which can be calculated by formula (6) or (7), as the case demands; and the ampère-turns required to overcome the reluctance of the tooth can be found, all as previously explained. This value can be plotted in Fig. 8 against the corresponding values of B_g, and the resulting curve shows the excitation required to overcome tooth reluctance for all values of the air-gap density. The curves for the air-gap proper will all be straight lines when plotted in Fig. 8. Let OR be the curve for the point a at centre of pole. Add the ampère-turns required for the teeth, and obtain curve (a), which gives directly the ampère-turns required to overcome reluctance of air-gap, teeth, and slots, for all values of the air-gap density. It will be understood that the ordinates represent the average value of the air-gap density at armature surface over a slot pitch. Any

FIG. 8.



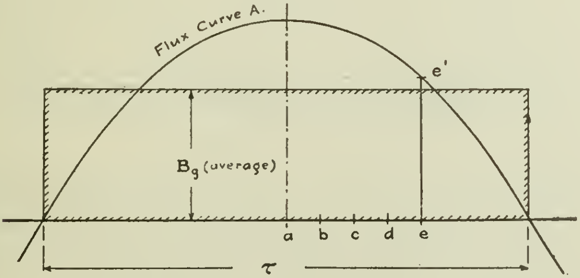
other curve, such as (d), is obtained by first drawing a straight line OQ such that PQ bears to PR the same relation as the ordinate at *a* in Fig. 5 bears to the ordinate at *d*, and then adding thereto the ampère-turns for the teeth, as already obtained.

FIG. 9.



The curves of Fig. 8 should include a sufficient number of points on the armature surface; and when the resultant M.M.F. between armature points and pole is also known—not only for open-circuit conditions, as already obtained, but for any desired condition of loading—the correct flux distribution curves can readily be plotted.

FIG. 10.



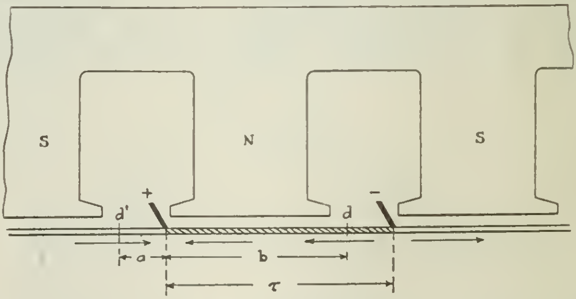
Let the curve of Fig. 9 represent the distribution of the resultant field M.M.F. on open circuit; then, at any point such as *e*, the M.M.F. is given by the length of the ordinate *ee'*. Find this value on the horizontal scale of Fig. 8, and the height of the ordinate at this point, where it meets curve *e* (which is not drawn in Fig. 8), is the flux density, which can be plotted as *ee'* in Fig. 10. In this manner the flux curve A of Fig. 10 is obtained. The area of this curve, taken between any given points on the armature periphery, is obviously a measure of the total flux entering the armature between those points. The required flux per pole is usually known. The average density over the pole pitch, τ, is, therefore, $B_g\ (average) = \frac{\phi}{\tau L_g}$

where L_g is the gross length of armature. By drawing the dotted rectangle of height B_g (average) as shown in Fig. 10, its area can be compared with that of curve A by measuring with a planimeter. If these areas are not equal, the ampère-turns per field pole, as represented by the curve of Fig. 9, must be altered, and a new flux curve plotted, of which the area must indicate the required flux.

EFFECT OF ARMATURE CURRENT IN MODIFYING FLUX DISTRIBUTION.

The simplest case being that of a continuous-current machine, this will be considered first. When the method of procedure has been explained, the modifications necessary to adapt it to alternating-current machinery will be discussed.

FIG. 11.



The distribution of M.M.F. over armature surface when the field poles are acting alone has already been calculated and plotted in Fig. 9, and the effect of the armature current in modifying this distribution may be ascertained by noting that the armature ampère-turns between any two points such as d and d' on the armature circumference (see Fig. 11) are $q\ (b-a)$ where q stands for the specific loading, or the ampère-conductors per unit length of armature circumference.

Let p = number of poles,

Z = total number of conductors on armature surface,

I_c = current in each conductor,

τ = pole pitch,

then $q = \frac{ZI_c}{p\tau}$

and the armature M.M.F. tending to modify the flux due to the field poles alone is,

$$0.4\pi\frac{ZI_c}{p}\frac{(b-a)}{\tau}$$

between the points d and d'.

In order that a curve may be plotted on the same basis as the resultant field M.M.F. curve, it is necessary to know the armature M.M.F. per pole at all points. Let the distance between the points d and d' be equal to the pitch τ, then the effect of the armature M.M.F. at d' upon the pole S will be exactly the same as the effect of the armature M.M.F. at d upon the pole N, and the M.M.F. *per pole* at the point d may be expressed as,

$$(\textit{Armature M.M.F.})_d = 0.4\pi\frac{ZI_c}{2p}\frac{(b-a)}{\tau} \quad \ldots\ldots\ldots (10)$$

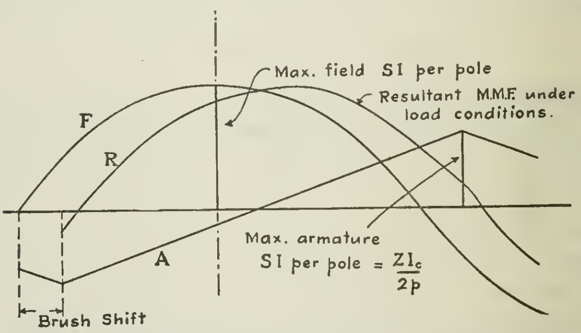
Its maximum value—which always occurs in the zone of commutation—is,

$$\textit{Armature M.M.F. per pole} = 0.4\pi\frac{ZI_c}{2p} \quad \ldots\ldots\ldots\ldots\ldots (11)$$

The combination of this armature M.M.F. with the M.M.F. due to the field coils only, as represented by Fig. 9, is carried out graphically in Fig. 12. The curves F and A represent field and armature ampère-turns (or M.M.F. in gilberts, if preferred). These are the two components of a resultant M.M.F. curve, R, the ordinates of which are a measure of the tendency to send flux from any point on the armature surface to the pole shoe N. The actual value of the flux density at the various armature points under load conditions can therefore be obtained by using the curves of Fig. 8 and plotting the values of air-gap density corresponding to the ampère-turns read off the curve R of Fig. 12. The procedure is exactly the same as when obtaining the open-circuit flux curve (Fig. 10) by using the values of Figs. 8 and 9; but the new curve of flux distribution—which may be called curve B, to distinguish it from the open-circuit flux curve A—gives the distribution over armature surface for a given brush position and a specified output. The difference in area of curves A and B is a measure of the flux lost through armature reaction: it includes not only direct demagnetization, but also cross magnetization which—by producing distortion of the flux distribution—leads sometimes to local concentration of high densities and reduction of total flux owing to saturation of the iron in the armature teeth.

The final flux curve for the loaded machine is generally similar to curve B, except that its area must be such as to indicate that the desired voltage will be generated. This increased area is, of course, obtained by increasing the field ampère-turns. In other words, a new curve F is required in Fig. 12 such that the curve R resulting from its combination with the existing curve A will produce a new flux curve similar to B, but of the required area. This new flux distribution curve may be called curve C, to distinguish it from the open-circuit curve A and the flux curve B, which, although a load curve, has too small an average ordinate to generate the required voltage. The amount by which the ordinates of curve F should be increased may be found by trial, but it is generally possible to estimate the necessary correction to give the required result. The added field ampère-turns may be thought of as compensating for two distinct effects:

FIG. 12.


Max. field SI per pole
Resultant M.M.F. under load conditions.
F
R
A
Max. armature SI per pole = $\frac{ZI_c}{2p}$
Brush Shift

(1) The loss of pressure due to armature reaction,

(2) The loss of pressure due to IR drop in armature, brush contacts, and series field windings.[12]

The correction for (1) consists in bringing the total flux up to its value on open circuit. It is the ampère-turns necessary to raise the average air-gap density from its value over curve B to its value over curve A. An approximate method of making this correction is to find on curve (a) of Fig. 8 (*i.e.*, the curve corresponding to point *a* at centre of pole) the ampère-turns P_bP_a required to produce the difference of flux density B_bB_a when OB_b = average flux density over curve B, and OB_a = average flux density over curve A. The correction for (2) consists in increasing the flux per pole to such an extent that it will generate the increased voltage. This is the correction for compounding; it compensates for all internal loss of pressure, and must include over-compounding if this is called for.

---

[12] In alternating-current machines the reactance drop has also to be considered.

If E' = required full load *developed* volts, and
E = open circuit terminal volts (being also the no-load developed volts), then,

$$\frac{\text{Area of curve C}}{\text{Area of curve A}} = \frac{E'}{E}$$

In this manner the required area of curve C is obtained. The average flux density must be increased in this proportion, and the necessary additional ampère-turns for this correction are arrived at approximately by making P_aP_c (as indicated on Fig. 8) such as to increase the air-gap density by the ratio of E' to E.

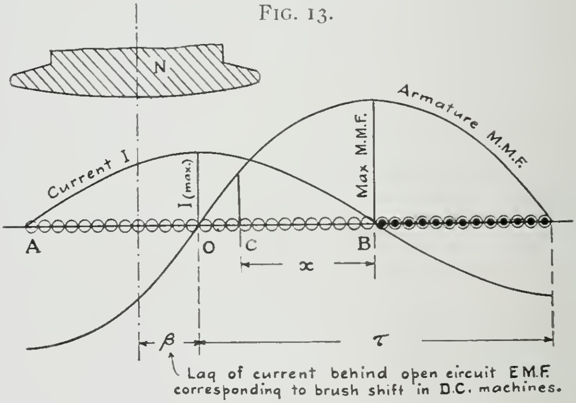
The area of the final curve C which should be measured for the purpose of checking with the required area, is that comprised between the points on the armature surface which correspond with the position of the brushes on the commutator: portions of the flux curve measured below the datum line being considered negative. and deducted from the area measured above the datum line.

ARMATURE M.M.F. IN POLYPHASE GENERATORS.

In a continuous-current machine the current has the same value at all times in all the armature conductors, and equation (10) shows how the armature M.M.F. follows a straight-line law over a zone equal to the pole pitch, this being the distance between brushes referred to armature surface. In alternating-current and polyphase generators the curve of armature M.M.F. can no longer be represented graphically by straight lines as in Fig. 9, because the value of the current will not be the same in all the conductors included in the space of a pole pitch.

Considering first the polyphase synchronous generator, and assuming a sinusoidal current wave, it is an easy matter to draw a curve representing the armature M.M.F. at any particular instant of time, provided the phase displacement—or position of the conductors carrying the maximum current—relatively to centre line of pole is known. If this be done for different time values, a number of curves will be obtained, all consisting of straight lines of varying slopes, the length of which relatively to the pole pitch will depend on the number of phases for which the machine is wound. The average of all these curves will be a sine curve, of which the position in space relatively to the poles is constant, and exactly 90 electrical space degrees behind the position of maximum current. This curve is most easily derived by assuming an infinite number of phases. Thus, the ordinates of curve I of Fig. 13 (assumed to be a sine curve) give the value of the current in the various conductors distributed over the armature surface. It is understood that the current in each individual conductor varies according to the simple harmonic law; but it is constant in value for a given position on the armature surface considered relatively to the poles. The direction of the current in the conductors between the points A and B may be considered as being downward, while the direction of the current in the adjoining section of width τ would be upward. The maximum value of the armature M.M.F., therefore, occurs at the point B, its value being:

FIG. 13.


N
Current I
$I_{(max.)}$
Max M.M.F.
Armature M.M.F.
A
O
C
B
x
β
τ
Lag of current behind open circuit E.M.F. corresponding to brush shift in D.C. machines.

Maximum value of armature ampère-turns per pole = average value of current in section OB × number of turns.

$$= \frac{2}{\pi} I_{max} \times \frac{Z'}{2p} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

where Z′ stands for the total number of armature inductors, counting all phases. This may be compared directly with formula (11), which applies to direct-current machines, by putting it in the form

Max. M.M.F. (gilberts) per pole

$$= \frac{0.4\pi \times 2 \times I_c\sqrt{2}\,Z'}{\pi \times 2p}$$

$$= \frac{0.4\pi Z_c'}{1.11 \times 2p} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (13)$$

where I_c stands for the virtual or R.M.S. value of the current in the armature conductors.

That the armature M.M.F. curve in Fig. 13 is also a sine curve when the current follows the sine law is easily seen from the general solution, thus:

At any point on the armature surface, such as C (Fig. 13),

$$(SI)_C = \Sigma \textit{ current} \times \textit{turns}$$

$$= \sum_{x=OB}^{x=CB} (I_{max.} \sin x) \times dx \times \textit{Number of conductors per unit length}$$

If x is expressed in angular measure (radians), the conductors per unit x are,

$$\frac{\textit{Number of conductors in space } \tau}{\pi} = \frac{Z'}{\pi p}$$

and

$$(SI)_C = \sum_{x=\frac{\pi}{2}}^{x=CB} I_{max} \, S \text{ in } x \, dx \frac{Z'}{\pi p}$$

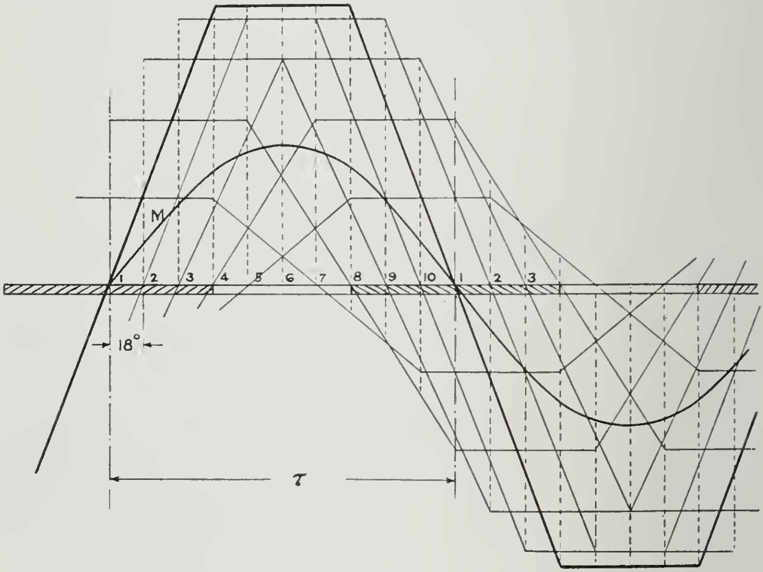
$$= I_{max} \times \frac{Z'}{\pi p} \cos (CB)$$

which agrees with the previously obtained maximum value of ampère-turns when the distance CB or x is equal to zero. The angle of displacement β (Fig. 13) of this curve relatively to centre line of pole depends upon the "internal" power factor, and also upon the displacement of the wave of developed E.M.F., a displacement or distortion which is due to cross magnetization. The angle β is not very easily predetermined, but, once known or assumed, the curve M can be drawn in the correct position relatively to the curve of field M.M.F.; and the resultant M.M.F. over the armature surface can be obtained exactly as for the direct-current machine (see Fig. 12).

ARMATURE M.M.F. CURVE OF SINGLE-PHASE ALTERNATOR.

When single-phase currents are taken from an armature winding, the M.M.F. due to this winding as a whole must necessarily be of zero value at the instant of time when the current is changing from its positive to its negative direction. This suggests that the magnetizing effect of the loaded armature on the field system will be pulsating; that is to say, it cannot be of constant strength at any given point considered relatively to the poles, whatever may be the phase displacement of the current relatively to the developed voltage. If the change of current in any given conductor be considered over a complete cycle, and if at the same time the position of this conductor relatively to the poles be noted, it will be seen that, *relatively to the field magnet system,* the armature windings produce a pulsating field of double the normal frequency. The actual flux component due to the armature currents will not, however, pulsate to any appreciable extent, because the tendency to vary in strength at comparatively high frequencies is checked by the dampening effect of the field coils, even if the pole shoes and pole are laminated. It is, therefore, the average or resultant armature M.M.F. considered relatively to the poles with which we are mainly concerned. The most satisfactory way of studying an effect of this kind is to draw the actual M.M.F. curves at definite intervals of time, and then average the values so obtained for different points on the armature surface, the position of these points being considered fixed relatively to the field poles.

FIG. 14.



This has been done in Fig. 14, where the windings are shown covering 60 per cent. of the armature surface, and the distance τ is one pole pitch. This distance is divided into 10 equal parts, each corresponding to 18 electrical degrees. The thick line represents the armature M.M.F. when the current has reached its maximum value. The armature is then supposed to move 18 degrees to the right of this position, and a second M.M.F. curve is drawn, corresponding to this position of the windings. Its maximum ordinate is, of course, less than in the case of the first curve, because the current (which is supposed to follow the sine law) now has a smaller value. This process is repeated for the other positions of the coil throughout a complete cycle, and the resultant M.M.F. for any point in space (*i.e.*, relatively to the poles, considered stationary) is found by averaging the ordinates of the various M.M.F. curves at the point considered. In this manner the curve M of Fig. 14 is obtained. It will be found to be of a sine curve, of which the maximum ordinate is half the instantaneous maximum M.M.F. per pole of the single-phase winding, and it may be used exactly in the same way as the curve M in Fig. 13 (representing armature M.M.F. of a polyphase machine); that is to say, it can be combined with the field pole M.M.F. curve to obtain the resultant M.M.F. at armature surface from which can be derived the flux distribution curves under loaded conditions.

The maximum value of the resultant ampère-turns per pole is, therefore,

$$\tfrac{1}{2} I_{max.} \times \frac{Z}{2p} = I_{max} \times \frac{Z}{4p} \ldots\ldots\ldots\ldots \quad (14)$$

where Z is the total number of armature face conductors. Expressed in gilberts the formula is,

$$\left.\begin{array}{l}\text{Maximum ordinate of arma-}\\ \quad\text{ture M.M.F. curve in single-}\\ \quad\text{phase alternator.}\end{array}\right\} = \frac{0.4\pi\sqrt{2}I_c Z}{2\times 2p}$$

$$= \frac{0.4\pi Z I_c}{\sqrt{2}\,2\,p} \ldots\ldots\ldots\ldots (15)$$

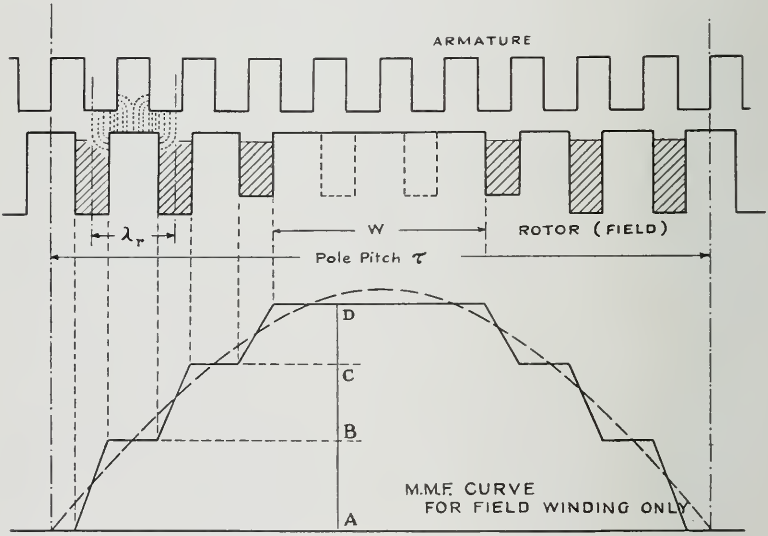
which, together with formula (14), may be compared with the formulas (12) and (13) for polyphase generators.

PREDETERMINATION OF FLUX CURVE IN HIGH-SPEED ALTERNATORS WITH DISTRIBUTED FIELD WINDING.

In the case of a slotted rotor carrying the field coils, and an air-gap of constant length—due to the fact that the bore of the stator or armature is concentric with the (cylindrical) rotor—the shape of the M.M.F. curve due to field excitation alone can readily be found without resorting to the somewhat tedious process of getting the permeance between pole and armature points, as described and recommended for salient pole machines.

If the whole surface of the rotor is provided with equally spaced slots, the average permeance of the air-gap between stator and rotor will have a constant value for all points on the armature periphery. This condition is represented in Fig. 15, if the centre portion of the pole, of width W, is slotted as indicated by the dotted lines. This constant average air-gap permeance can be calculated within a close degree of approximation by making conventional assumptions in regard to the path of the magnetic lines, as was done in the case of the salient pole machines when deriving formula (1) giving the permeance at centre of pole. The flux lines can be supposed to be made up of straight lines and quadrants of circles; and if the permeance over one tooth pitch is worked out for different relative positions of field and armature, very satisfactory results can be obtained by this method. It will usually suffice to make the calculations for one tooth pitch in the position of greatest permeance, and again in the position of lowest permeance. The average of these calculated values, divided by the area of the tooth pitch in square centimetres, will

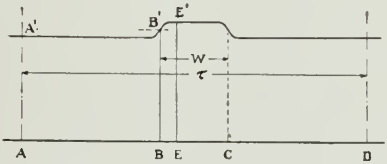
FIG. 15.



give the average value of the air-gap permeance per square centimetre.

Under this condition of constant air-gap permeance, the flux distribution on open circuit will follow the shape of the M.M.F. curve; but, in any case, since $B = M.M.F. \times$ Permeance per sq. cm., the flux curve can always be obtained when the M.M.F. distribution is known. Thus, if the portion W of the pole (Fig. 15) is not slotted, the permeance curve, instead of being a straight line of which the ordinates are of constant value, would be generally as shown in Fig. 16. From these values of the permeance per square centimetre of armature surface, curves such as those of Fig. 8 can be drawn, so as to include the reluctance of the armature teeth. From all points on the armature between A and B, and C and D (Fig. 16), the average air-gap permeance would have the value AA'. Over the central portion W it would have the value EE', while, in the neighborhood of the points B and C, it may be assumed to have an intermediate value as indicated by the ordinate BB'.

FIG. 16.



If the depth of the slots in the rotor has been decided upon and the number of ampère-conductors in each slot determined, the distribution of M.M.F. over armature surface due to the field winding can readily be plotted as in the lower sketch of Fig. 15. Thus the ampère-turns in the coil nearest the neutral zone are represented by the height AB, those in the middle coil by BC, and those in the smallest coil by CD. The broken straight line so obtained is best replaced by the dotted curve, which takes care of fringing, and represents the average effect. This curve, being the open-circuit distribution of M.M.F. over armature surface for a given value of exciting current, may be combined with the curve of armature M.M.F. to obtain the resultant M.M.F. under loaded conditions. The flux curves A and B for open-circuit and loaded conditions can, therefore, be derived by proceeding exactly as in the case of the salient pole designs.

With salient pole machines variations in the open-circuit flux distribution can be obtained only by shaping the pole shoes so as to alter the air-gap over the pole pitch in a manner which is not easily determined except by trial, but with the field winding distributed in slots it is not difficult to arrange the coils to give any desired distribution of M.M.F. over the pole pitch. Thus, if the desired flux curve is known (a sinusoidal distribution is usually best for alternating-current machines), and if the average permeance per square centimetre of the air-gap has been calculated, an ideal M.M.F. curve can easily be drawn, since, at every point, the M.M.F. is the ratio of the flux density to the permeance per square centimetre. The spacing and depth of slots can then be arranged to produce a magnetizing effect as nearly as possible the same as that of the ideal curve.

CONCLUDING REMARKS.

A study of the flux distribution in dynamo-electric machines, by plotting curves as outlined above, appears to the writer to offer many advantages, of which a clearer conception of the fundamental physical phenomena is by no means one of the least important. In continuous-current machines it is an aid to the study of commutation troubles, and, since the maximum value of the flux density can be determined, the maximum voltage between commutator segments under different conditions of loading can be calculated. In alternating-current machines it leads directly to the determination of wave shapes under various conditions of running, and it should be very helpful in designing machines to give as nearly as possible a sine wave E.M.F. at all loads. The usual text-book conception of demagnetizing and cross-magnetizing ampère-turns as distinct components of the armature M.M.F., capable of being separated and treated vectorially, is abandoned, and the reaction of armature on field is dealt with more scientifically because the saturation of the teeth and the effect of high densities in limiting the amount of distortion are considered. The chief advantage, however, lies—as previously mentioned—in the fact that new types of machines, or radical departures from existing types, can be designed, and their performance predicted, without reference to empirical formulas or test data, the application of which would be a difficult matter for the designer, whose experience and judgment might, indeed, be unequal to the occasion.

ARTISTIC PAINTING AND THE OLD MASTERS.*

BY

MAXIMILIAN TOCH,

Director, Research Laboratory, Toch Brothers, New York, N. Y.
Member of the Institute.

That between the fourteenth and the seventeenth centuries artistic painters possessed secrets which account for the permanency of their paintings, and that the manufacture of pigments for artistic painting is a lost art and for that reason no modern painting can be considered permanent, is the general impression throughout the world to-day.

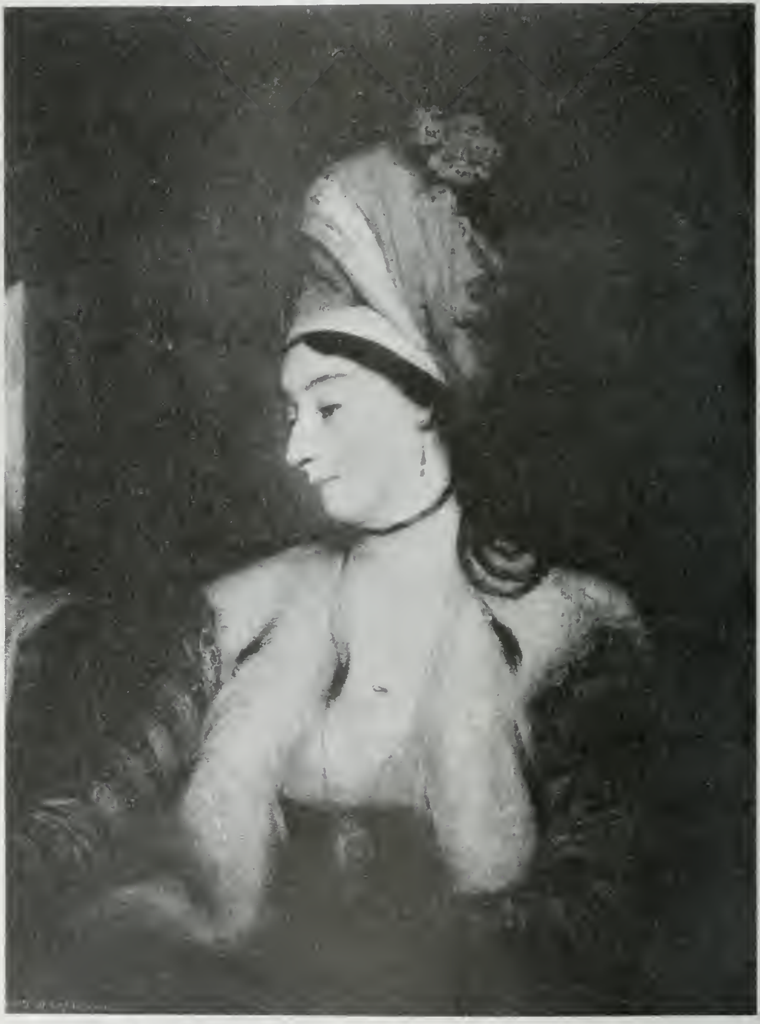
The first artistic oil painting of which there is any record was executed in the year 1399 by Hubert Van Eyck, a Dutchman, and it was to him and his brother, Jan, that the credit is given for having invented or originated oil paintings. This may or may not be a fact, for there are records indicating that decorative oil painting was applied in the eleventh and twelfth centuries in England, and invoices rendered for such work are also in existence. However, painting with oil to produce artistic results was, without doubt, no sudden discovery, but was a gradual development, and only as improvements in it were made from time to time was there attained any degree of perfection.

Much has been written on the subject of the secret of the old masters, which was supposed to consist in the use of pigments which have never been imitated, and of vehicles or oil media with the composition of which we are at the present day still unfamiliar. The belief in this secret was very marked in the middle of the eighteenth century, and, in fact, many artistic painters themselves held the opinion that the Dutch and Italian artists were possessed of a profound secret. Sir Joshua Reynolds gave much credence to the myth—for myth it was—and kept copious notes on the subject, and he himself was in continual search of the secret.

Sir Joshua Reynolds, a most remarkable painter and as good a portrait painter as ever lived, was, unfortunately, very impractical and comparatively ignorant, and did not possess the remotest idea of how to confirm by experiments whether the secrets that he was continually discovering possessed any value or not. Sir Joshua was a most prolific painter, executing throughout the three busiest years of his life an average of three finished portraits a week.

---

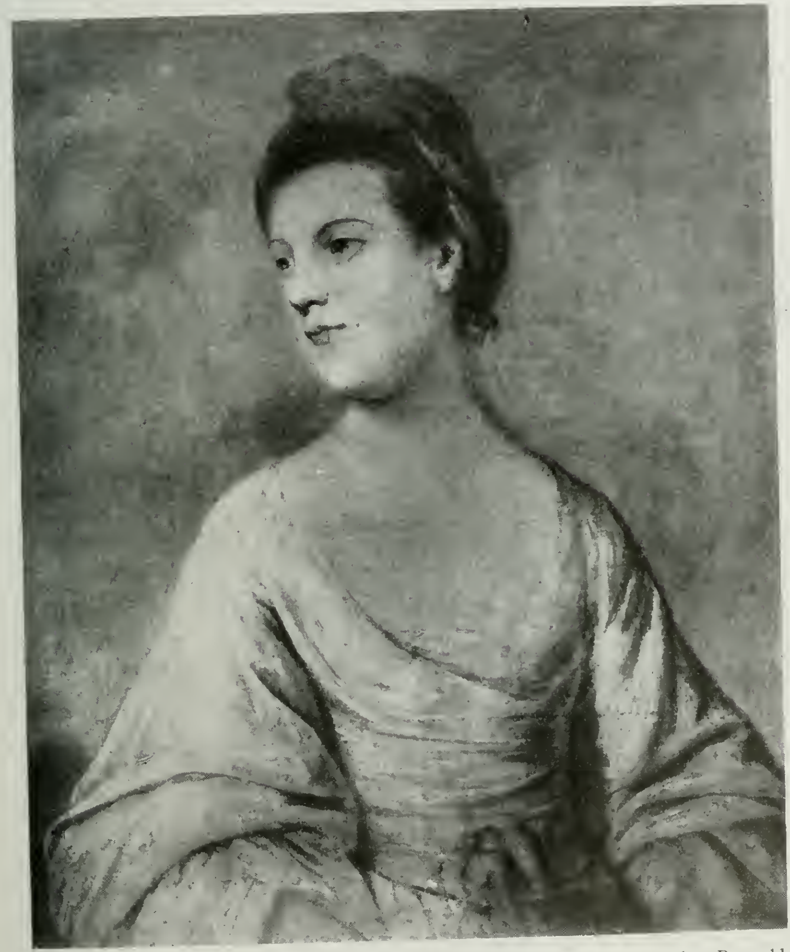
* Presented at the meeting of the Section of Physics and Chemistry, held Thursday, November 5, 1914.



The Metropolitan Museum of Art

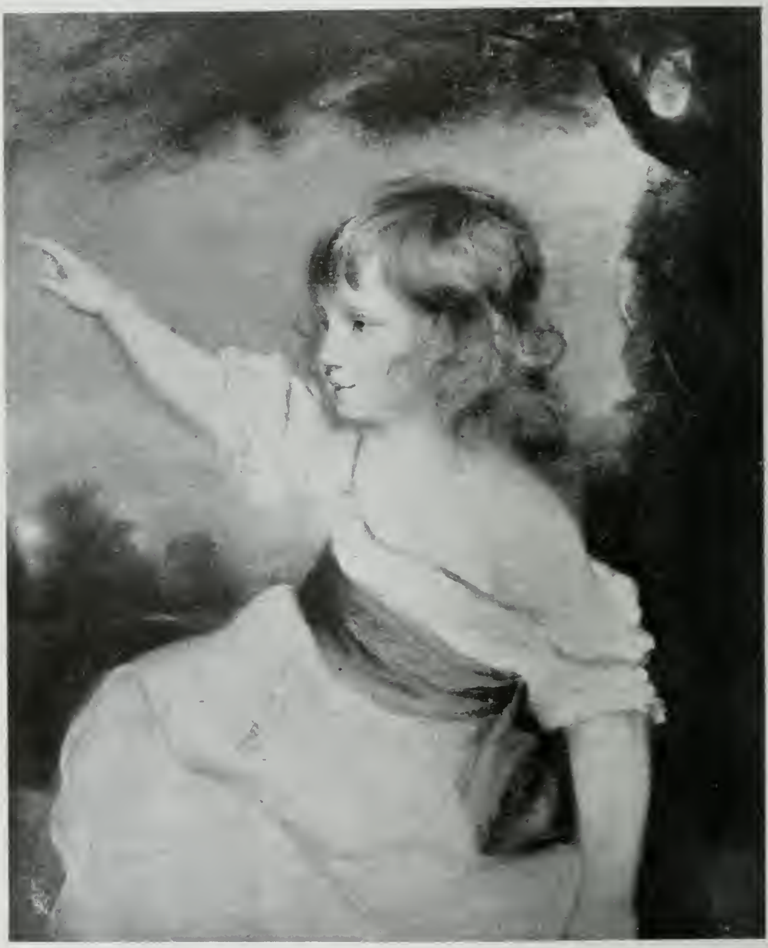
Painting by Sir Joshua Reynolds in which the face has bleached practically into a monotone, due to the fact that incompatible pigments were used. The dress and turban and background are still in excellent condition, and evidently were painted by one of his students.

He was well known in London in his day, and was just as popular then as Edison is now. He was invited to every function, public or private, and had he attended he would have had no time left for his work. He had a number of students, many of whom possessed great ability, and it is said on excellent authority that of every person who came to him for his or her portrait (and it



This is one of the most striking examples of the decomposition of Sir Joshua Reynolds's paintings, and the photograph is even better than the original. The original is practically of a "putty" color, and the line of demarcation of the lips shows up better in the photograph, for certain photochemical reasons, than is portrayed in the original. This is undoubtedly due to the mixture of an organic lake with one of the metallic pigments in the experiments of Sir Joshua Reynolds.

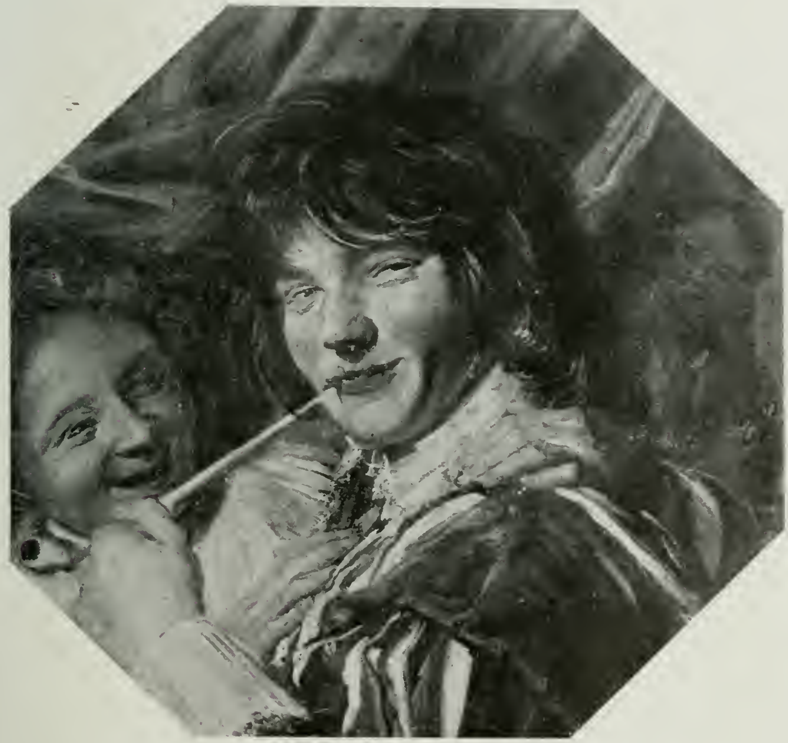
was the fashion in those days to have a Reynolds portrait made) he himself painted the face and the hands only, leaving the background and dress to be done by his pupils. Indeed, had he painted the entire portrait, it would have been physically impossible for him to have painted three a week, and the further fact that his students did paint the background and the dress is undoubtedly the reason that at this very day many of his beautiful pictures



The Metropolitan Museum of Art

Painting of the portrait of an infant by Sir Joshua Reynolds, in which even the red of the lips has faded, and the painting now appears as if it were painted in two colors.

which have faded are still perfect in these particulars. There are some of his pictures—and I have in mind three of them in the Museum of New York—in which the face and the hands have bleached out, and practically nothing is left but a smudge. This is probably due to the fact that every time Sir Joshua was on the verge of discovering the supposed secret of the old masters he tried it on the first sitter that came in, and invariably it failed.



The well-known picture of "The Smoker," by Frans Hals, in which it is plainly evident that the red of the cheeks and the red of the lips on which madder lake was used was painted over the bottom color after the bottom color was thoroughly dry.

Frans Hals was the first impressionistic painter, and, as he used brushes with handles six feet long, all his paintings look their best at a distance of more than six feet.

Just as careless as was Sir Joshua in his experimental work or in trying out mixtures with results he had no notion of, so careless was he in copying likenesses, and the result was that hundreds of pictures were thrown back on his hands and were sold after his death. Of course, there are many of his works still in existence which are very good and are fairly preserved.

One of the peculiar practices of Reynolds was to mix a lake color with an earth color, when the two were incompatible. Now it happens that a flesh tint can be produced, and has been produced from time immemorial, by a mixture of an earth known as yellow ochre, a little white pigment, and madder lake. Each of these three by itself is permanent, but when mixed each one undergoes a very slow chemical decomposition. This decomposition produces a change of color, as is well illustrated in the case of yellow ochre and madder lake mixed together; when first mixed the result is a bright flesh color, but in six months the color has changed to a sickly, pale, ghastly mud color.

Two centuries before Reynolds, Frans Hals, than whom, perhaps, no better portrait painter ever lived, was well aware of the incompatibility of colors, and his wonderful Flemish characters, with their red cheeks and redder noses, are still as lifelike to-day as they were three hundred years ago. This was because Hals carefully allowed one color to dry before he put another over it, and he also used the so-called permanent madder lake as a glazing color to produce his effects.

Another potent factor in the permanency of the older paintings is that the early Italian and Flemish painters had possibly eight or nine pigments only. To-day there are over two hundred pigments, but no painter need be fearful about the permanency of his colors if he will use only those which are known not to interact.

Madder lake has a very interesting history. There is every reason to believe that the Egyptians used it, and that madder constituted their red dye. The color is extracted from the roots of a plant called the *Rubia tinctorum.* It has been known for generations that if this plant is boiled with a solution of alum a red coloring matter develops and the alum fastens it. In the South of France cultivation of this plant became a great industry, and in order to encourage it the French Government decreed that the trousers of all the French military uniforms should be dyed red with madder lake, and that is why to this very day the soldiers of the French army wear bright red trousers. A peculiar point in this connection of the development of the madder industry is that thirty years ago a method of making madder lake synthetically was discovered in Germany. The product was made from coal tar and is known as alizarine, and for more than twenty years the French Government used this product in place of the genuine madder lake, and the cultivation of the madder root has become almost a lost art.

Up to about fifteen years ago the usual method employed by experts in judging whether paintings were real or spurious was the "subconscious" method. This is the same method we all use when, say, we receive a letter written by a person of our acquaintance with whose handwriting we are thoroughly familiar. By the subconscious characteristics of the writing we can judge the genuineness of the letter, as there are very few, if any, people who write absolutely alike; and so when a picture is put before an expert he tells by the same instinct whether it is genuine or not. Within the last ten or fifteen years, however, the identification of pictures by more scientific methods has been practised. Some experts, in employing these methods, make microscopic analyses of pigments, and others—one in particular, Professor Laurie, of Edinburgh—photograph sections of paintings with a microscope, and then compare the enlarged detail of brush work of the picture under inspection with that of one of known origin. There are clever paint imitators who can paint pictures which are so closely like the original that the "subconscious" method is of no avail in detecting them and the scientific investigator must always be consulted. Thousands of spurious paintings, copies of the late masters and copies of the modern ones, which have been passed as genuine, and which have been sold for enormous amounts, are in existence. All works of art are imitated in the same way, and the identification of a spurious piece of work is sometimes difficult. We find furniture imitated to perfection; we find ancient pottery and bronzes, old weapons and brass work so completely simulated that experts are frequently baffled. Sheraton furniture is a familiar example. Sheraton had a little shop and did most of his work himself, but occasionally employed a few expert artisans to help him. The amount of so-called genuine Sheraton furniture in existence is so great, however, that Sheraton would have had to employ a thousand men in a factory covering several acres if he had made all the furniture which is supposed to be genuine Sheraton.

Rembrandt lived for sixty-three years, and for forty-five years was active as a painter. So far as is known, some seven hundred pictures were painted by him, and yet I have made an estimate, which is probably incorrect, that there are fully between four and five thousand pictures in existence, for all of which great prices have been paid, and all supposed to be genuine Rembrandts.

Peter Paul Rubens, who was born in 1577 and died in 1640, spent over forty years of his life painting, and some of his pictures took fully a year, because they are so perfect in detail, so large, and so carefully executed. There is no doubt that many of his pictures were partly painted by him and partly by his scholars, and yet it would have been absolutely impossible for any human being to have painted all the Rubens that there are in existence. In fact, this may be said of every great painter, modern or ancient.

There was an auction sale last year in the city of New York, at the Plaza Hotel, at which some of the best works of George Inness were sold. One particularly fine piece which had already been on exhibition, and the origin of which no one doubted, was placed on sale; but as it was about to be sold the son of the famous painter had it withdrawn, stating that he was familiar with every painting made by his father, and he believed the one about to be sold to be an imitation.

Some picture dealers whose reputation is questionable have peculiar and remarkable methods for marketing their spurious wares. Of course, many have been discovered, but very few of them have been prosecuted. One in particular was caught in a very novel manner. He possessed a most excellent picture painted on a panel, and this he offered to a collector at a ridiculously low price. After the purchase the dealer asked the buyer to write his name on the back of the panel so that he would be sure of getting his purchase and no other picture. When the purchaser received his picture he found his own handwriting on the back of it. Being somewhat skeptical, however, he felt that the picture sent to him was not the one he had bought. He waited for six months and then sent a friend to this dealer, and the latter brought out the (very) picture which he himself was supposed to have originally purchased. The dealer made the same request for the buyer's signature. The second purchaser wrote his name on the back of the picture, paid for it, but insisted on taking it with him. The second picture was later examined very carefully and was found to consist of a genuine on top and an imitation beneath, the latter being painted on a thinner panel. The second buyer had written his name on the imitation, and it developed the first had done the same.

An interesting case happened in London only a few years ago, showing how good imitations can be sold and stamped as genuine through fraud and chicanery. There was a painter in London who was a most clever imitator, and who copied a large number of the old Dutch and the semi-modern English painters. A dealer called at his studio and offered to buy his entire works on condition that he himself should leave the country. The sum offered was sufficiently inducive, and the painter sold all the imitation masterpieces he had and went abroad. Thereupon the dealer, in connivance with a lawyer, conceived a unique scheme for placing these pictures on the market. The lawyer attempted to serve a summons on the artist to recover an amount of money ostensibly loaned on these paintings, and, finding his studio closed, applied to the court for permission to enter it and sell at auction all the effects found therein. After due service of the summons by publication, the court issued an order that the effects of the defendant be sold at public auction, describing in detail all the spurious masterpieces as supposedly genuine paintings, and thereupon all the effects of the defendant were taken to a very prominent auction room in London and placed on sale. There was outwardly no question as to whether the paintings were genuine, because the Supreme Court, in issuing judgment, had stated that the effects consisted of "four Rubens, three Reynolds, and one Gainsborough, and a large number of other prominent and well-known masterpieces." The auction sale created at the time a great deal of interest in London because there had never been offered for sale at any one time such a large number of masterpieces. The amount which the lawyer and the dealer realized was enormous, and to this very day those who purchased these pictures would probably never have discovered the fraud if the artist himself had not read of the sale and felt it his duty to come back and expose the whole matter.

As regards the scientific methods of determining the originality of paintings, I have mentioned the method devised by Professor Laurie, of Heriot-Watt College, which consists in a photomicrographic method. Professor Laurie analyzes the brush work of a known masterpiece and compares it with the one in question, and the analogy of the strokes indicates the genuineness. There is another method, which I can best describe by relating a case in which two pictures were in dispute and the case was settled purely on scientific grounds. A well-known collector in New York bought a small picture by Rembrandt for $15,000, and all who saw the picture agreed that it was genuine. The collector felt, however, that he was paying too much for the picture, as it was in rather poor condition and not a very good example. The dealer thereupon offered in addition a very excellent Ruysdael, which was dated 1650, and was in fine condition. Ruysdael was a Dutch landscape painter, and one of the first prominent of such. Three hundred years ago, for every landscape painted there were probably one thousand portraits painted, and this painter is known for his excellent scenery. A number of prominent experts viewed this Ruysdael, and they all agreed, according to the "subconscious" method, that it was not genuine. The dealer protested, and, as a matter of fact, it was very difficult to prove whether it was genuine or not, for if it was spurious it was reasonable to infer that the Rembrandt was also spurious, although that, too, was very difficult to prove. As a last resort a scientific expert was engaged, who removed from the face of the painting three small pieces hardly larger than the eye of a needle, and from the back of the picture a small section of the oak panel on which it was painted. After a week he reported to this effect:

"This painting is an imitation, but it is probably between fifty and seventy-five years old, for the following reasons:

"1. The white pigment used in the sky is made of zinc oxide and not of flake white. Three hundred years ago zinc white was not known, and the Flemish painters used flake white.

"2. In the shadows the bitumen used is still transparent. Bitumen three hundred years old is converted by light into carbon, and becomes insoluble.

"3. A microscopic section of the wood on which the picture is painted shows that the protoplasm or 'living matter' in the cells has not entirely dried out. Wood which is three hundred years old shows no such protoplasm.

"4. I therefore pronounce this painting an imitation for the above-mentioned reasons."

The dealer then acknowledged the Ruysdael was an imitation.

One of the reasons that the ancient paintings have lasted so long as compared with some of the modern is the fact that the condition of the atmosphere in a modern city is so totally different now from what it was prior to the invention of some of our modern conveniences. For instance, in the city of New York the air contains a perceptible amount of sulphuric acid, due to the burning of hard coal. In the city of Pittsburgh and in the city of London the air contains other acids, and coal dust in addition. The influences of coal gas and the products obtained from burning illuminating gas are sufficient to have a serious effect on paintings. Then, again, light and darkness are important factors in the preservation of pictures. Light bleaches and darkness blackens, and a painting which remains in a dark corner for six months turns yellow wherever oil or an oil varnish was used on it.

In restoring paintings one of the simplest methods and one of the most efficient is, after wiping them free from dust and dirt, to place them in the bright sunlight for two or three days, and the sunlight will bring back the colors, excepting such modern lake colors as are faded by the sun, in all their pristine glories.

Another destructive agent to paintings in homes is the gases derived from the cooking of vegetables. Certain vegetables contain a large amount of sulphur, which is easily liberated, particularly in the presence of vinegar, and this sulphur affects colors, particularly those containing white lead, lead pigments, and others. To a very large degree varnishing preserves paintings from the influence of gases, but, of course, the varnish used must not be made with a drier which contains any chemical affected itself by gases.

I mentioned already the interaction of one color on another. Ultramarine blue, which is perfectly permanent by itself, when mixed with flake white and subjected to the influence of an acid gas changes in color from a sky blue to a dirty brown. This mixing of compatible colors is another reason for the deterioration of paintings, and one or two examples will suffice to indicate to you why paintings deteriorate. The modern schools, like the Cubists for style and the Impasto for technic, are very unfortunate. As regards artistic style I have nothing to say, because that is another subject; but the Impasto is the method used by many painters in which they pile up pigments until the painting itself is plastic to a certain degree. In other words, bushy eyebrows are not portrayed so much by light and shadow effect as by piling up paint on the eyebrows until a really plastic form is produced. If painters of three and four hundred years ago did this, nothing is known of it, because there are no paintings of that time in existence which were painted by this method, for the obvious reason that they could not have been permanent; and, therefore, painters of to-day ought to be warned against this method of piling up paint, because within twenty or thirty years a painting of this type will consist of dried-out pigment, which will fall off the canvas by its own weight. I have seen modern impressionistic painters who piled on their flat colors with a mottled effect, and in less than two years the paint dropped from the canvas; it can therefore be recommended that every painter use simple pigments, simple oils, and not too copious an application of paint. Where glazed effects are desired, the best results are obtained when one coat is applied over the other coat after the first is thoroughly dry and hard. All the newer media which give quicker and better results may be useful when applied to paintings to be used for making illustrations in colors only, but if the painting is to be permanent and is intended as a work of art for future generations, the best materials to employ are simple pigments and linseed oil. As an illustration of this, the great French painter, Vibert, with whose paintings, particularly "The Schism," every one is familiar, devised the idea that a resin similar to ordinary resin and a volatile liquid like gasoline or benzene would make a most excellent medium, for it would dry quickly, the colors would be permanent, and the oil itself would have no chemical action on the pigments. Theoretically this is true, but practically it proved a failure in time, and this excellent painter did not live to see the decomposition of his own works. A few months ago I viewed Vibert's excellent painting "The Schism" at the National Gallery in Washington, and I asked the curator of the gallery whether he knew that this excellent example of Vibert, for which I think the National Museum paid a large sum, was beginning to decompose and the pigment was leaving the wood on which it was painted. This is actually the case, but I hope some one will be able to devise a method whereby this excellent picture will be preserved. As it is now, the surface is badly pitted, and in a few years the paint will drop off almost entirely.

RECENT DEVELOPMENTS IN CAST-IRON MANUFACTURE.*

BY

J. E. JOHNSON, JR.,

Consulting Engineer and Metallurgist, New York, N. Y.

Founding is one of the early arts and undoubtedly had its origin at the time of the development of the blast furnace in the latter middle ages. It has made its greatest progress, however, since the methods of using mineral fuel in this furnace have cheapened the product of the latter so much that ninety per cent. or more of that product is now nothing more than the raw material for the production of steel. The art of founding was almost ignored by the scientific metallurgist until within comparatively few years. The developments in the manufacture of steel were so rapid and of such vast importance to the whole of mankind that practically all the labors of iron and steel metallurgists were devoted to steel, and the foundryman was left to struggle along as best he could on the basis of his hard-earned, and sometimes contradictory, practical knowledge and experience. In the nineties of the last century was brought about a great change in this condition, for chemistry began to be applied freely in the foundry, and by its aid many facts in connection with its manufacture of cast iron were brought out. Some of these facts the practical men declared were not true, and the conditions of cast-iron manufacture are so complex that many are still in dispute.

In 1900, the closing year of the decade referred to, I published in the *American Machinist* an article in which, to my mind, was made the first definite and coherent statement of the nature of cast iron, particularly in its relation to steel. The following are some quotations from this article:

> . . . the key to the subject lies in considering cast iron and steel not as entirely separate and distinct, but as the same substance, passing by infinitesimal gradations from the chemical and physical properties of one extreme to those of the other. The probable reason that this fact is not more

---

* Presented at a joint meeting of the Philadelphia Section of the American Society of Mechanical Engineers and the Mining and Metallurgical Section of the Institute held Thursday, October 8, 1914.

widely realized than it is, is that both of the extreme conditions are "soft"—soft gray iron and soft or mild steel—while the connecting link between them is the hardest of tool steel at one end and the hardest of white iron at the other, with no sharp lines separating them from one another.

There is no doubt that there could be made in a blast furnace, from the proper materials, an iron containing silicon 0.2, manganese 0.4, phosphorus 0.03, sulphur 0.03, combined carbon 2.75 per cent., graphitic carbon, trace.

But excessively hard crucible steel may be made having precisely the same analysis, and both have practically the same properties. The crucible steel is so hard and brittle that it cannot be commercially rolled or hammered, and is of no value, as well as being extremely difficult to make, while the greatest care and effort, and probably several weeks or even months of trial, would be necessary to produce an iron with the composition given, in a blast furnace, and when produced it would be of little commercial value; so that a material having this composition is seldom or never produced—never commercially—and we are not, therefore, familiar with it, and do not realize the fact, which it is impossible to emphasize too strongly in this connection, that it exists, or may exist, and constitutes a perfect link between cast iron and steel.

Since soft iron contains the most total carbon (about 4 per cent.) and very mild steel the least (say, 0.06 per cent.), while the intermediate stage, the very hard iron or steel just described, contains about the average of these two, roughly speaking, and is so much harder than either as not to resemble them in its properties, this may be thought to weaken or invalidate the above statement; but it does not, when properly considered, for, while the total carbon is high in the cast iron, almost all of it is in the graphitic form and only a trace is combined.

If we say, "Cast iron and steel are alloys of the chemical element iron with carbon, with a chemical and physical admixture of other compounds, and the hardness of the alloy depends, within commercial limits, upon the amount of the carbon in it, while its tenacity, ductility, and other physical properties depend upon the other substances present, and upon the physical treatment it receives, and the variations produced by these are approximately the same in both," we shall have a blanket definition of the two substances which covers both quite fully and with substantial accuracy.

Too much stress can hardly be laid upon the two kinds of carbon in cast iron, the "combined" being chemically united or combined with the iron to form a chemical compound; the other, the graphitic, being merely interspersed among the grains or crystals of the iron. The most striking proof of this latter is that shown a few years ago, I have forgotten by whom, which consists in brushing with a steel-wire brush the fractured face of a pig of gray iron, one-half of which is protected from the action of the brush; the brushed half becomes perfectly white, like white iron, although the grain, of course, remains as before. The unbrushed half, of course, shows the contrast more plainly.

Iron, when hot, has a far higher capacity for dissolving carbon and retaining it in combination than it has when cold. The graphitic carbon is probably all in solution at first, although this is not certain. But as the iron cools, if it cools slowly, the graphite is forced out and what is near the surface flies off into the air. It can be seen doing it at a blast-furnace cast when the iron is of the proper composition. The rest is retained, immeshed in the grains of the iron, and probably gives to gray cast iron whatever toughness and flexibility it possesses, separating the grains or crystals from continuous contact and lubricating their movements.

Thus hard cast iron, while much less flexible, is much more elastic than soft, as it should be, having much less graphitic carbon in it. The more slowly the iron cools the more graphite crystallizes out of it and the larger the crystals, so that comparatively hard iron, when cast into large masses and allowed to cool for several days, or longer, will show a grain which would put "No. 1 X" to the blush.

. . . .

The tendency to eject carbon and become softer, in consequence, does not by any means stop when the iron is solid, nor until it is down to the lower limit of the red heat at least, and how much lower the writer will not undertake to say. When any casting was made from moderately hard iron which it was required to machine, it was always kept carefully covered up until dead cold, and this was known by experience to be very necessary. Some intentionally "chilled" pieces, when made of very hard iron, would "fly" off themselves from the cooling strains set up, but could often be saved by keeping them hot as long as possible.

When the iron is cooled suddenly, the carbon does not have time to separate out, and remains combined with the iron, making it "white" instead of gray, because of the absence of the black graphite.

I think that this is a reasonably good presentation in a broad way of our knowledge of the subject to-day. It is a matter of interest that, in the subsequent part of the above article, is to be found the statement that the only reason for the use of charcoal iron, particularly for chilling purposes, was that, charcoal being free from sulphur, iron as low in silicon as desired could be produced in the charcoal furnace without any important simultaneous increase in the sulphur above that in high silicon iron, which could not be done in coke furnaces until shortly before that time, but that it could be done then at will, and that charcoal iron had accordingly no advantage over coke iron, and was destined to pass out of use. This is probably as good an illustration of assuming that all the facts fit an incomplete theory and drawing a totally erroneous conclusion in consequence as you will find anywhere in technical literature, and it is my particular purpose to point out the important respect in which charcoal iron differs fundamentally from coke iron, and to describe the method by which we have succeeded in obtaining, for a modified form of coke iron, the advantages of charcoal iron in a greater degree than are obtainable by it.

In 1901, the year following the publication of my article, Professor Henry M. Howe read a paper before the American Institute of Mining Engineers, in which the theorem of the continuity of the cast iron-steel series was set forth more elaborately and in far better language than in mine. Professor Howe pointed out that the important question in regard to the carbon in cast iron is not what is the total carbon, nor yet how much is thrown out as graphitic, but how much is *left combined,* because it is upon the quantity of combined carbon in the matrix that its strength depends.

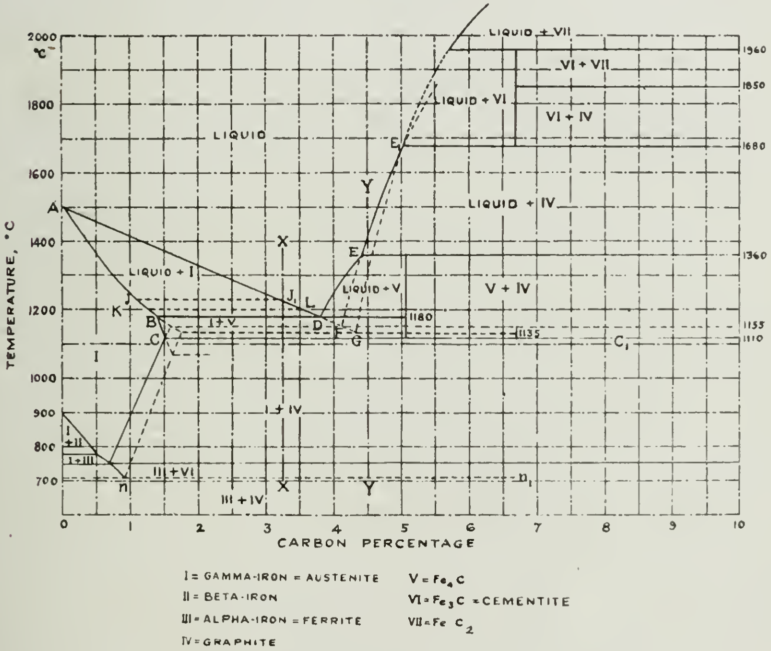
It seemed to me at first that this statement put the matter in a nutshell, and was obviously correct. It will be seen later that Professor Howe's is also an incomplete theory, and that certain other factors enter in of so much greater importance in the final result as almost to eclipse the truth contained in his statement taken by itself.

From the quotations I have made, it is obvious that cast iron must be considered primarily as an alloy of iron and carbon. This is quite proper in a more elementary sense, because carbon is present in iron quantitatively to a greater extent by weight and to a far greater by volume than is any other element. Carbon has, moreover, a more powerful effect, weight for weight, than any other element except one.

THE IRON-CARBON DIAGRAM.

The Iron-Carbon Diagram, as applied to cast iron by Guertler based upon researches of Wittorff, is shown in Fig. 1. In Fig. 2 is shown a similar diagram drawn by Upton. Both of these have been obtained through the kindness of Professor William Campbell, of Columbia University. You are all probably familiar with the general form of these diagrams. The abscissas represent percentages of carbon, and the ordinates temperatures. The diagram, within its range, attempts to set forth the changes which occur in any solution of iron and carbon. A horizontal line runs across at the temperature of 1180° C., and two diagonals drawn respectively from the upper right- and left-hand portions meet upon this line at the point corresponding to 4.2 per cent. of carbon in Upton's diagram, at 3.8 per cent. in Guertler's. The diagrams attempt to show not only equilibrium conditions,—that is to say, those conditions which prevail after the mass has been allowed sufficient time in cooling to reach a complete state of equilibrium,—but also metastable conditions. The interpretation of certain of the transformations is extremely difficult. I will not try at this point to make an exposition of the complete diagram, but will only call attention to its salient features. Considering Guertler's diagram and starting with a molten solution above the diagonal line on the left-hand side, we have a homogeneous solution—let us assume one whose composition is represented by the line *XX*. When the temperature falls, the composition remains constant until point *A* is reached, when, if ample time be allowed for the cooling, a solid freezes out, whose composition at any temperature is given by the intersection of the horizontal through that temperature with the line *AB*, in the present instance the line JJ_1, shown on the diagram. The metal represented by the point *J* obviously contains less carbon than that of the whole mass represented by the abscissa of the line *XX*, and the carbon rejected by

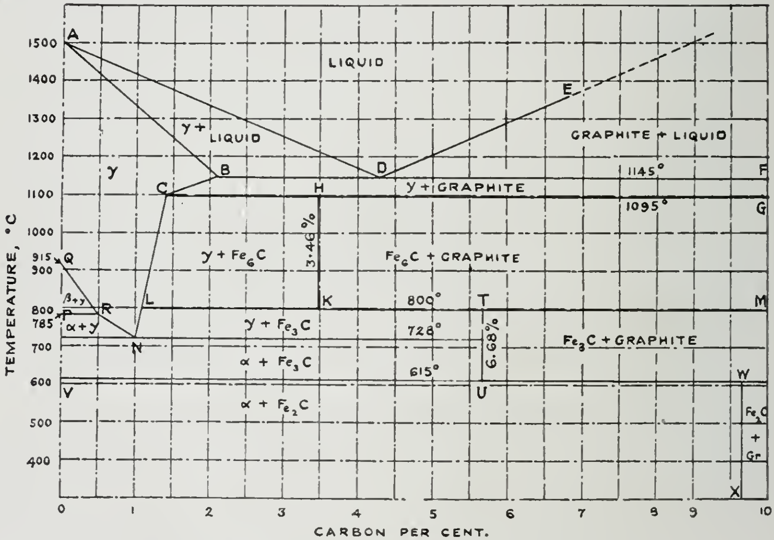
FIG. 1.



GUERTLER'S IRON-CARBON DIAGRAM

this solution in freezing must go over into the remainder of the solution, and so increase its carbon. If sufficient time is not allowed in cooling through any range, for instance that from *JJ*$_1$ to *KL*, the carbon from the solution is not able to diffuse into the solid and bring the percentage up to that represented by the point *K*, but tends more to follow the vertical line from *J* to *K*. This takes less carbon from the solution and leaves the excess in it greater. We have, therefore, the curious condition that the more rapid the cooling the greater the difference in carbon contents of the first and last frozen portions of the original metal.

FIG. 2.



G. B. UPTON'S IRON-CARBON DIAGRAM

After the metal has fallen in temperature below the line *BD*, it is entirely solid, but is not yet in its permanent condition, because carbon tends continually to fall out of solution. The method by which this takes place is subject to various conditions, and is not yet fully understood, even among the scientists who deal with this phase of the subject, as will be clearly seen by the difference between the lower portions of Fig. 1 and Fig. 2, which are intended to represent the same set of objective phenomena.

The following brief statement of the possibilities in regard to the transformation of these points is quoted from my reply to the discussion of my paper, "The Effect of Oxygen, etc.," before the Institute of Mining Engineers, published in its *Bulletin*, June, 1914, and was prepared for me by Professor Campbell, through whose kindness I am able to present here three possibilities based on the work of Guertler (who founds his conclusions upon the experiments of Wittorff and Ruff) and one based on Upton's iron-carbon diagram. According to Guertler:

I. In the stable condition above 1360° C. and 4.4 per cent. C., we can have liquid + graphite.

At 1360° C. the reaction occurs; liquid + graphite = Fe_4C, and in alloys with 4.4 per cent. carbon down to 3.8 per cent. we find Fe_4C crystallizing out from the melt.

At 1180° C. we have the eutectic of austenite + Fe_4C.

At 1110° C. Fe_4C breaks up into austenite + graphite.

At 750° C. the eutectoid of ferrite and graphite forms.

These are equilibrium conditions which are reached only with extremely slow cooling.

II. With more rapid cooling, the reaction at 1360° C. does not occur. Graphite separates from the melt, and at 1155° C. we get the eutectic of austenite + graphite.

III. With more rapid cooling, Fe_3C separates out from the melt and at 1135° C. and 4.3 per cent. carbon forms a eutectic with austenite; then at 710° C. we have the eutectoid Fe_3C + ferrite, commonly known as pearlite.

According to Upton's diagram, white irons are super-saturated solid solutions which are breaking down; and the stable constituents are austenite + graphite above 1095° C.; austenite + Fe_6C or Fe_6C + graphite below 1095° C.; and at 800° C. Fe_3C appears while Fe_6C disappears. At 600° C. F_3C breaks down into Fe_2C. Fe_6C and Fe_2C have yet to be distinguished from Fe_3C under the microscope.

Leaving this for the present, let us consider the conditions represented by an iron-carbon alloy, containing more carbon than that represented by the point *D* on both diagrams. Assume, for instance, iron of a composition represented by the line *YY*. According to both diagrams, when the temperature has fallen to the point where line *YY* cuts the right-hand branch of the curve solidification begins; but in this case it is either Fe_4C, graphite, or Fe_3C which is thrown out of solution.

The relationships expressed by the dotted lines *FE* and GE_1 are too obscure for description at this point, though we may revert to these briefly after examining the action of a few of that infinite variety of alloys answering to the comprehensive name of "cast iron."

In either case, it is well to remember that, when the temperature falls slowly, the iron tends to follow the one or the other of the branches of the curve in cooling. If a hypoeutectic iron,—that is, one lying to the left-hand side of the point *D* (for instance, the composition represented by the line *XX*),—selective freezing tends to take place along the line *AB*, with a resulting concentration of carbon in the mother liquor, represented by the distance between the lines *AB* and *AD* on the horizontal line corresponding to the given temperature. But if sufficient time be not allowed, then the iron tends to freeze in a purer (that is, lower carbon) condition, with a greater enrichment in this element of the mother liquor.

On the other side of the eutectic point *D* the hypereutectic iron tends in freezing to follow along one of the lines *DE*, *FE*, or GE_1, and in any event this corresponds to the falling out of graphite, or a carbide which, being richer in pure carbon, leads to a direct proportional impoverishment of the mother liquor; and this impoverishment in this case is greater if time is allowed for full equilibrium to be reached, and less if this time is shortened.

When the whole mass has solidified, it is at the temperature represented by the points *D*, *F* or *G*, and consists of a mixture of different constituents, and the character of this mixture depends upon the original composition of the iron-carbon alloy and its rate of cooling from its initial temperature to that of the freezing point. This mixture generally contains graphite physically enmeshed, if it be a hypereutectic iron.

Below the line CC_1 it is obvious, from the diagrams, that their authors disagree considerably as to the details of the action, but further graphitization goes on, and the solution of pure iron in cementite becomes poorer and poorer in carbon until the line nn_1 is reached, when a very important transformation takes place. All the solid solution remaining breaks up into pure cementite in all detached areas and into pearlite, one of the best known constituents of all irons and steels, and one which can perhaps best be described by reference to the fact that 0.9 carbon steel, in its unhardened condition, consists entirely of this material. Pearlite is well known as one of the strongest and toughest of the countless combinations of iron and carbon.

Even at this low temperature, 725° C. or 1337° F., barely a dull red, the iron is not yet in equilibrium. The cementite may break down to pure iron and graphite in relatively large masses. Pure iron or ferrite is only about one-third as strong as pearlite, and, of course, when its continuity is broken up by graphite it is thereby further weakened, and, being in large areas, its effect in weakening the whole structure is very great.

The line *DE* of Upton's diagram may be entirely disregarded, since it is well known that the actual line is much steeper and is probably, nearly if not exactly, as drawn on Guertler's diagram, which is more recent than that of Upton and is based on the researches of Wittorff, the most recent and probably the most accurate of any of the investigations on high-carbon alloys of iron.

Upton's diagram is shown principally for the reason that it contains the vertical line *HK*, since it has been found by actual experience that irons with more than a certain quantity of carbon graphitize to a much greater extent than similar irons containing less carbon, and that high carbon irons not only throw out more graphite than do lower carbon ones, but the combined carbon remaining is very materially less in the high carbon irons than it is in the low. The line *HK* indicates such an action, and is, therefore, to some extent in agreement with the observed facts, although I am quite unable to state whether the exact location of the line at 3.46 per cent. carbon is correct.

From the point of view of practical value, two possibilities according to these diagrams stand forth prominently.

1. Graphite can separate directly from the melt. This is contrary to the claims of Professor Howe and Professor Sauveur, but is abundantly supported by the facts. Their contention that

this action can take place only through the prior formation of cementite is completely negatived by facts of practice which are matters of common knowledge to furnacemen.

2. After solidification, according to Guertler and Upton, in certain areas of the diagram a very slight change in conditions may cause a complete change in the resulting product.

The iron-carbon diagram gives graphically the best information we have concerning the action of alloys of pure iron and carbon, but cast iron is far removed from that theoretical material, as it contains, in addition, silicon, sulphur, phosphorus, manganese, and sometimes oxygen, generally, if not always, in vastly varying quantities. There may be also titanium, vanadium, chromium, and nickel and perhaps many other elements present, but the first five are the important ones in commercial pig irons. Each of these exercises its principal action upon the carbon and upon its condition, and as a result we would need in practice a complete diagram of the form given for each. To represent graphically, for instance, the effect of carbon and silicon together, we would require a figure of three dimensions, or, in other words, a solid or "glyptic model." In addition, for each percentage of each of the other elements there would be a variation of this model to express all the facts. The effect of three elements would occasion a model of four dimensions! As a matter of fact, however, we have not as yet sufficient information to make a single iron-carbon diagram with absolute certainty, nor do we know very definitely the quantitative effects produced by given quantities of the other elements I have mentioned. We must needs, therefore, confine ourselves to a consideration of the qualitative effects of the above elements on the iron-carbon solution.

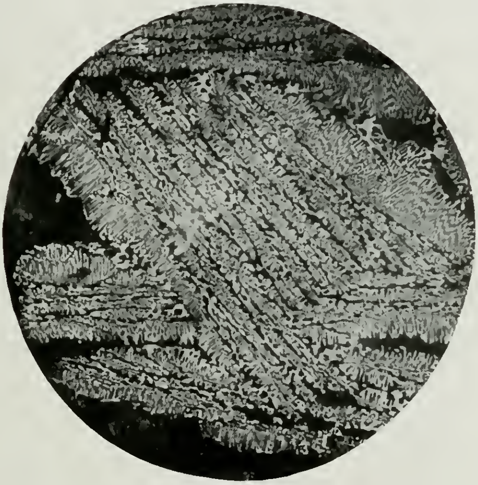
THE SHAPE OF THE GRAPHITE AND THE FORM OF THE CRYSTALS.

Before dealing with the effects of the other elements, I wish to call attention to two profoundly important facts, no intimation of which can be found in the iron-carbon diagram and the effects of which cannot be recorded upon it. They are, however, of vast industrial and, I think, scientific importance, and are also two factors in the final result to which I shall have occasion to refer frequently. The first is the shape of the graphite particles, and the second the form of crystallization in which the iron solidifies.

The shapes in which graphite can occur vary immensely, and have a corresponding effect upon the structure as a whole. Graphite is, to all intents and purposes, a foreign substance in iron. In other words, we could make a steel of the same composition as a good cast iron, counting only the combined carbon, and could by suitable heat treatment bring the combined carbon into the same condition as in cast iron, and have a homogeneous material of the same nature but free from these particles of a virtually foreign substance; this would constitute an impure steel.

The smoothness and lubricating qualities of graphite are well known, as is also the fact that it is entirely without physical strength. To intersperse flakes of this material thickly through cast iron can have obviously no other effect than to break its continuity and destroy the bonds with one another of the particles of iron proper. Good gray iron contains about 3.0 per cent. of graphite, and the specific gravity of this is about a fourth that of iron. This corresponds to about 12 per cent. by volume.

FIG. 3.

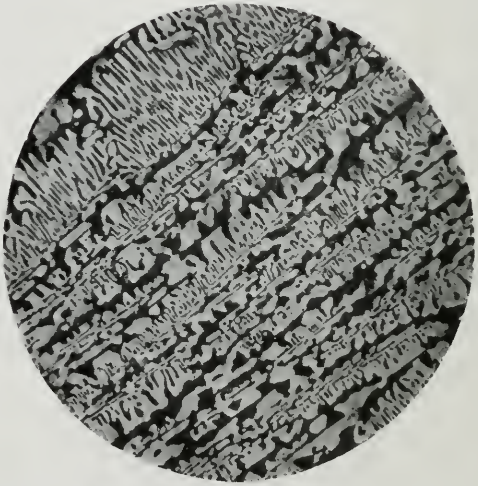


Etched. (Magnified 38 diameters.) Spot of spotted iron.

One of the things which we have discovered is that graphite in some iron is of extreme thinness and of vast extent, while in other iron it exists in scarcely more than little round knots or balls. Consider this enormous percentage by volume and the extreme thinness of the plates of graphite, which, judging from the photomicrographs, are probably less than 1/1000 of an inch thick, and you will see what an enormous area they must have to make up 12 per cent. of the volume, and what a vast amount of damage they must do to the structure of the iron.

If we were to make up concrete and add to it 12 per cent. by volume of, say, tin scrap in small, irregular pieces, about 1 inch across, and well greased to prevent the concrete from adhering to them, and were to stir these thoroughly through the mass, and then pour the mixture into a form, do you think that the resulting concrete would be particularly valuable? If, now, instead of tin scrap an inch across, we used iron balls of about the same specific gravity and to the same extent by weight, and stirred those thoroughly through the mass, can you doubt which concrete would be the better?

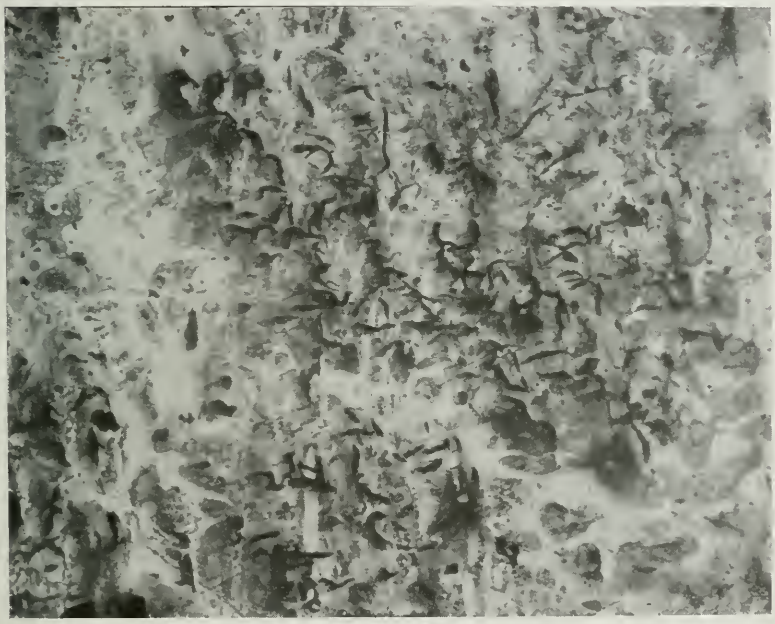
Fig. 4.



Etched. (Magnified 100 diameters.) Spot of spotted iron.

As to the form of crystallization, the eutectic of 4.20 carbon crystallizes from a pure iron-carbon solution in a series of flat plates, the cross-section of which is similar to that of a number of fern leaves laid side by side, as shown by the photomicrographs, Figs. 3 and 4. In certain kinds of iron these plates grow so large as to be plainly visible to the naked eye. When they remain white, they are as smooth as if polished, and shine brilliantly when their surfaces are exposed. If you imagine a series of blocks of mica thrown loosely into a mould, and a cement or glue poured in to fill up the spaces between, and the resulting structure subjected to stress, you would not expect to find it very resisting, no matter how good the cement, because the blocks would cleave apart on the smooth faces of the mica. It is the same with iron which has this crystallization. No matter how good its chemical composition may be, even if the combined carbon be of the exact amount to give the greatest strength, the iron will be weak and worthless.

FIG. 5.



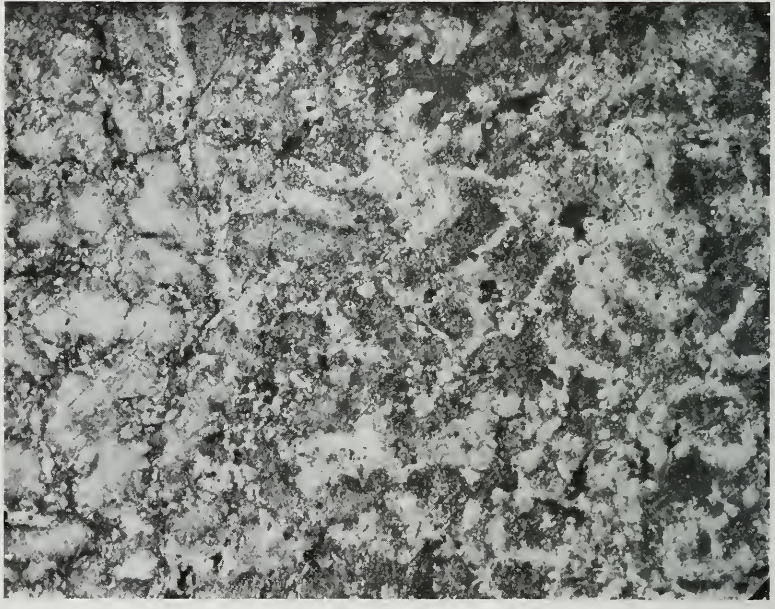
Etched. (Magnified 100 diameters.) Good charcoal iron, showing meshwork structure.

If, on the other hand, even the concentration which comes from progressive freezing results in the formation of little or no eutectic, the solution freezes into a network structure, which I have supposed is the same as that in the steel named by Professor Howe "Primaustenoid." The best illustration of this structure I have is that shown by Figs. 5 and 6. I think you will see that the structure as a whole is vastly more homogeneous than the eutectic and quite lacking in the lines of cleavage which give the latter its bad qualities, but that such lines of crystallization as do appear are in the form of a meshwork, so that the whole structure, where not absolutely homogeneous, is interlaced together.

These are the two facts which render the amount of graphite, and even the percentage of combined carbon, matters of secondary importance, and which minimize the value of Professor Howe's brilliant generalization on that subject.

The qualities by which different irons are distinguished from one another are very many. I have classified them as follows: strength, flexibility, elasticity, density or closeness of grain, fluidity, freedom from shrinkage, and machinability. These represent qualities generally desirable, but the importance of some is the greatest in one class of work and of others in other classes of work; in fact, advantages for one class of work may be positive disadvantages for another. These are matters which depend upon the purposes for which the castings are to be used, and need not be discussed in detail here.

FIG. 6.



Etched. (Magnified 100 diameters.) Coke iron with oxygen added. First heat of Johnson iron ever made. (Photograph due to kindness of Prof. William Campbell.)

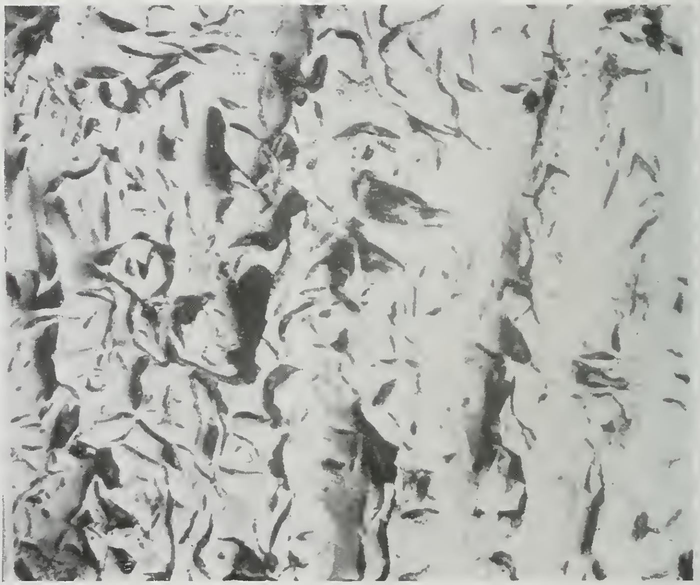
Let us return now to the elements of prime importance—carbon, silicon, sulphur, phosphorus, oxygen, and manganese—and consider the effects which varying quantities of each of these may have upon each of above qualities of prime importance. You will see that we have here a practically unlimited number of combinations, and that it is virtually impossible to do anything more than to discuss the general results of the variations of the elements within the range of practice in different lines of foundry work.

CARBON.

The subject of the effect of variations of carbon on cast iron has been neglected far too much. The carbon determination in cast iron is a difficult one, and unless made by a man with considerable experience along this line is of no value. Errors to the extent of 1 per cent. of the weight of the iron (not the carbon) have frequently been made by good and conscientious chemists through the difficulty of manipulation and, until recently, through the absence of suitable apparatus for the purpose. At the Ashland plant of the Lake Superior Iron and Chemical Company, where the researches whose results I am about to give you were begun, we introduced a long silica tube heated by an electric resistance coil, with a pyrometer to control the temperature, and burned the carbon in a stream of purified oxygen, catching the carbon dioxide in barium hydrate solution and determining its amount by titration—practically the same method as used for carbon in steel. We became so convinced of the importance of carbon determinations that we put an extra man into the laboratory in order to obtain one on every cast. Even with this excellent apparatus it took months to learn necessary temperature control and other precautions which must be taken to secure correct results. The difficulties are greatly increased by the fact that one iron will be heated to incipient fusion and sintered by a given temperature, thus sealing up some of the carbon and giving a low result, while another iron at the same temperature may not be hot enough to give off all its carbon and may show a low result on that account. I believe these difficulties of making carbon determinations at all, and of securing dependable results when they are made, have militated more against the progress of cast-iron metallurgy than any other factor.

The results of variations in carbon and their effect on the form of crystallization were set forth at some length in a paper by myself, read before the American Institute of Mining Engineers and published in 1912, entitled " Effect of High Carbon on the Quality of Charcoal Iron." The results we obtained have been briefly mentioned above, and were that iron of the eutectic ratio crystallizes in smooth, flat plates without cohesion between either the plates in one group or between those of one group with those of another. If the iron is above the eutectic ratio,—that is, of a composition represented by the right-hand branch of the iron-carbon diagram, —the excess carbon above the eutectic ratio falls out in the form of graphite as the iron cools down one of the lines DE, FE, or GE_1, and in that event, of course, the whole mass, except the ejected graphite, is at the eutectic ratio at the point of solidification and freezes as a mass of eutectic, perhaps interspersed with the particles of hypereutectic graphite. During cooling after solidification, if the silicon be high enough it forces the decomposition of the eutectic plates into ferrite, pearlite, and

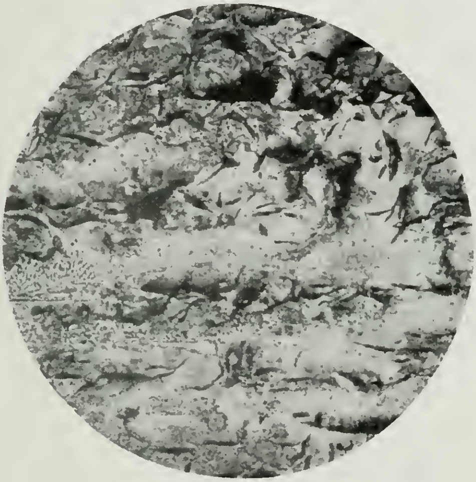
FIG. 7.



Unetched. (Magnified 70 diameters.) High cleavage iron, showing rows of graphite flakes oriented after eutectic plates from which they were focused.

graphite. These are formed in the solid condition and necessarily have the orientation of the plates of eutectic from which they are born, and, in consequence, high carbon irons, when they have sufficient silicon to make them gray, have an appearance of high cleavage, especially around the corners of the pigs and at other points where they are quickly cooled. These cleavage planes are black or gray, but are of the same general character as the brilliant white plates which occur in the same iron when it is white or mottled. They are the result of the breaking down or graphitization of the original eutectic plates (Figs. 7 and 8).

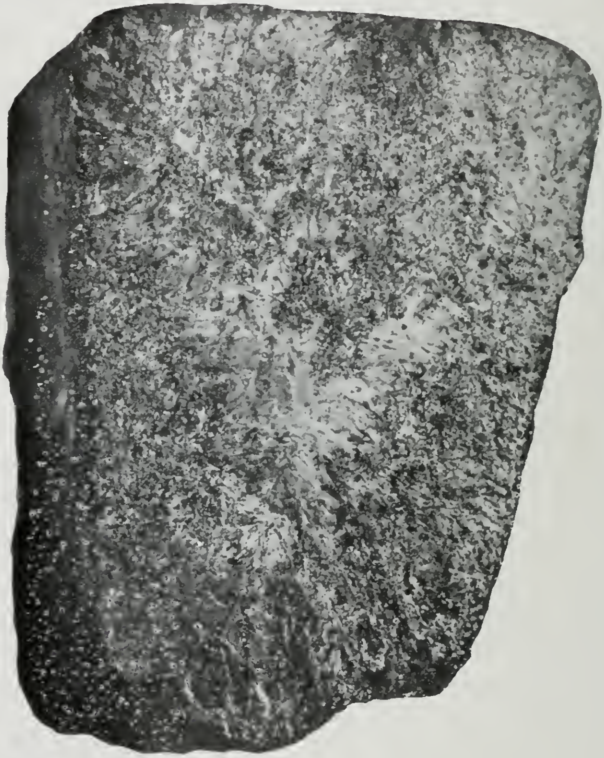
FIG. 8.



Etched. (Magnified 70 diameters.) Same as Fig. 7.

These irons have been noted for a curious peculiarity; ordinarily we expect to see the part of the iron cooled first white and the part cooled last gray, if there be any white or any gray at all, which means that the white is outside and the gray is in the centre. But in these irons the outside of the pig is gray, while there is a white chilled spot in the centre, or just above the centre, of the pig (Fig. 9). This curious phenomenon has caused much racking of wits, especially during the course of our investigation at Ashland. Finally, it occurred to me that this spot occupied the position which a segregate would take. An analysis of the spot and other portions of the pig showed that there was indeed a segregation. In irons of moderate carbon, the portions first frozen are well below the eutectic ratio, but the portions last to freeze have the carbon concentrated in them by the selective action of freezing and therefore crystallize in the eutectic form. It is well known that the evolution of graphite is accompanied by a considerable increase in volume, and, if this be resisted with sufficient pressure, graphitization cannot take place, and the iron must remain white. I have seen a white spot produced in the centre of a pig of good iron by cooling the exterior very rapidly. This took away the heat from the outside, while the centre still remained hot enough to retain its carbon in the combined condition. The resulting contraction of the outer metal prevented the graphitization of the centre, which would have

Fig. 9.



Typical fracture of "spotted iron."

taken place as the temperature fell, by preventing the necessary increase in volume.

It had previously been suggested by Mr. H. E. Field that this spot was caused by the pressure resulting from the contraction of the outer shell of first frozen metal upon it, but, as all pig iron solidifies under these conditions and only a small portion of it contains this spot, this solution was obviously inadequate.

The reason for the automatic formation of the white spot in these spotted irons is probably to be found in two factors:

First.—The segregate at the centre is the eutectic, and therefore has a freezing-point very decidedly lower than the outside, so that the shell is thoroughly solidified and able to exert a considerable pressure when the centre is still molten.

Second.—These spotted irons occur only within a limited range of silicon, from 0.8 per cent. down to 0.3 or 0.4. The former limit of silicon is sufficient to force graphitization, even against the resistance of the external shell. Below the latter limit the iron is practically all white, although in the case of a high carbon iron it may be heavily specked with primary graphite scattered between the blocks of eutectic plates which constitute the body of the structure.

In regard to spotted iron, it is a matter of observation that an iron may show a " spot " if quickly cooled, but will not do so if cooled slowly. For instance, the 1¼-inch test bars made at every cast at Ashland would sometimes show a spot when the pigs did not. This is evidently because of the fact brought out in the explanation of the iron-carbon diagram that the quicker the cooling and the less time allowed for the diffusion of the carbon into solidified portion of the metal, the greater the carbon concentration in the last frozen portion. Iron which, when slowly cooled, is far enough below the eutectic ratio not to undergo sufficient carbon concentration to show a " spot," undergoes, when quickly cooled, a greater carbon concentration, because there is not enough time allowed for the diffusion of the carbon throughout the mass, and so shows a spot.

These high carbon irons were noted among practical men for very deficient chilling power, a fact amply confirmed by observation of the " chill pig " at Ashland, of which one was cast in every bed, these irons having only a fraction of the chill which they should have for a given silicon. This action, may, I believe.

best be explained by reference to the well-known law of physics, that a solution of, say, common salt may be cooled below the point at which it can theoretically retain the amount of salt which was dissolved at a higher temperature, and may, if kept quiet, retain the excess to a temperature considerably lower than that of equilibrium; but if a single crystal of salt be dropped into the solution, the excess will instantly crystallize out around it, and the solution will at once drop to the equilibrium ratio. So in iron, if it be cooled more rapidly than will permit it to reach equilibrium, under ordinary conditions more carbon will be retained in combination than the equilibrium ratio would call for, but when the mass is filled with graphite flakes deposited from the molten condition (which, as I have explained, takes place with these irons) these graphite flakes act as centres of precipitation and cause *more* carbon to fall out of the solution than would do so if there were *less* total carbon present. Thus, by the aid of the microscope and with a little help from the iron-carbon diagram, we find the explanation for the characteristics of these irons easily translatable into terms of analysis, namely, their high carbon content, and so solve this long-standing riddle.

In this connection, it must be pointed out that, while 4.2 per cent. is the eutectic ratio for a pure iron-carbon alloy, the eutectic point is lowered by the addition of silicon, and probably reaches to 3.8 per cent. or even lower when the silicon reaches about 2 per cent. or more. On the other hand, other things being equal, the total carbon falls as the silicon rises beyond, say, 0.5 per cent., because carbon and silicon exert to some extent a mutually exclusive action upon each other, exactly as water saturated with calcium chloride will not take up as much common salt at a given temperature as will pure water. So, as the silicon in iron rises, the carbon falls until we reach "silvery iron"—which is a much lighter gray than ordinary iron because of the small quantity of carbon present, in spite of its being entirely graphite, the carbon with 4 per cent. silicon probably falling to below 3 per cent., as against nearly 4 per cent. in coke iron, and sometimes almost 5 per cent. in spotted charcoal iron of about 0.5 per cent. silicon.

On the other hand, the carbon falls from this point (about 0.5 per cent. silicon) as the silicon falls, because these irons are made in a colder hearth. The temperature of the iron as produced is not sufficient to enable it to take up its maximum carbon. The fact that at this silicon percentage occurs the maximum carbon is probably also a factor in the occurrence of spotted irons within a limited range on either side of this point.

While it has been demonstrated that high carbon leads to certain exceedingly objectionable qualities in iron, it is, nevertheless, not to be assumed that high carbon is always bad, or that the lower the carbon the better the iron, since this is far from true. The hardness of chilled iron depends largely upon its content of iron carbide. This compound contains 6.66 per cent. of carbon, so that an iron with even 4 per cent. of carbon is less than two-thirds carbide or cementite. The farther we fall below 4 per cent., the smaller the percentage of carbide which can be formed from the carbon present, and, other things being equal, the softer the chill in the same proportion. In order to obtain the benefit of the high carbon, we must be able to retain the carbon in the combined condition and not have it thrown out as graphite either before or after freezing; this, you will see later, we now have a means of doing. For chilling purposes, therefore, the carbon in iron needs to be high. When the carbon falls much below 3 per cent. the character of the metal seems to change. It is probably for this reason that steel scrap, with a mixture of which by good practice castings can admittedly be made strong, can only be used in a limited proportion in chilled castings, because, if used to a greater extent, it dilutes the carbon of the whole charge so much as to impair the hardness of the chilled material.

So far as the blast furnace is concerned, we do not need to concern ourselves with carbon lower than about 3.5 in any ordinary range of silicon, since, so far as my knowledge goes, furnaces seldom make lower carbons than this under normal working conditions, although a furnace too cold to function properly has often been known to produce what is virtually wrought iron, which, of course, has too high a melting-point to run from the furnace and which causes endless trouble in consequence.

The lowest carbon I have ever seen was 3.03 per cent. This was a charcoal iron produced when the furnace was in trouble. Such an iron contains much oxygen-bearing material, which reacts with the carbon and causes the metal to be filled with a great mass of blowholes, so that each pig swells up to the section and general appearance of a well-made loaf of bread, and makes the material worthless for commercial purposes. This is known as " Spongy. No. 6."

The melting-point of the iron-carbon alloys, as may be seen from the diagrams, Figs. 1 and 2, falls from 1500° C. for pure iron to 1180° C. at the eutectic point. The lowering of the melting-point taking place along a straight line and being, therefore, proportional to the increase in carbon, consequently if the carbon be lowered to too great an extent, the melting-point becomes so much raised as to make the metal difficult to handle in the cupola, and this rise in temperature exerts a certain very detrimental influence on high-class iron, which will be shown later.

For strength alone there seems to be no doubt that a reduction in the carbon is good, even below 3 per cent., but it is probable that only material ranging from 3 per cent. to 5 per cent. in carbon should be considered cast iron. The vast majority of all the iron produced lies within the comparatively narrow limits of 3.5 to 4.25 per cent.

The other elements exert an influence on the amount of carbon which iron can contain, and also on the eutectic ratio, but these influences will be better discussed, in so far as they are known, in connection with the elements concerned.

SILICON.

Next to carbon, this is the most important component of cast iron. It varies in ordinary iron from 0.2 up to 4.0 per cent. Above 4.0 per cent. the iron passes into the field of "silvery" iron and from thence to ferro-silicon. It is extremely difficult to make iron containing less than 0.2 per cent. silicon in the coke furnace without having the sulphur run up to prohibitive limits. In the charcoal furnace iron can be produced with silicon as low as 0.10, or 0.15 in good white iron. The lowest I have ever seen it was 0.03, but this was in the spongy white iron of which I have spoken above.

Various investigations have been made as to the effect of the addition of silicon to steel. Sir Robert Hadfield conducted an extensive research on alloys of iron and silicon several years ago; this can be found in the *Journal of the Iron and Steel Institute*, 1889, vol. ii, p. 222. The effect of silicon on steel (and therefore upon the matrix of gray iron also, in a general way), within the ordinary limits in which it occurs in foundry iron, was not particularly marked, but when the silicon rose above 3.5 per cent. it diminished the ductility of the steel materially. I have already pointed out that the strength of the matrix of gray iron proper is far less important than the extent to which it is cut up by graphite, and for this reason within ordinary limits we do not need to consider very seriously the relatively slight effect of silicon upon the metal itself (that is the matrix), but its effect upon the carbon. This, as is well known, is to force the carbon out of the combined condition into the graphitic, and this action takes place not only above the melting-point, but also down to relatively low temperatures. It is best illustrated by the fact that ordinary coke iron of more than 1.0 per cent. silicon will not show a white chill when cast against a chill block. Under any ordinary circumstances, this silicon is sufficient to force the graphitization of the carbon, in spite of the sudden cooling. Below this percentage the chilling power of the iron is roughly inversely proportional to the amount of silicon present. The iron begins to show a chill as cast from the furnace a little below 1 per cent. At 0.75 silicon it will show ordinarily one-quarter inch of white chill; at 0.5 silicon, ½ inch chill; and at 0.25 silicon it will chill clear through a depth of 2 or 3 inches, and will show much white in the pig even when slowly cooled. The completeness with which carbon is thrown out of the combined condition in unchilled iron is, in a rough way, similarly proportional to the silicon present. With 2 per cent. silicon an ordinary coke pig iron will hardly show more than 0.25 per cent. combined carbon, but the amount left in the combined condition will rise as the silicon falls, until it may be as high as 1.0 per cent. throughout the mass without the casting being chilled white on the surface, when the silicon goes down well below 1 per cent. These figures are subject to modification by considering half a dozen other factors besides silicon, and are correct only in a general way for average conditions. Definite figures are only given with great reluctance to avoid glittering generalities which sound well and mean so little.

Apart from this influence on the carbon, silicon, when it rises above 2 per cent., has the effect of hardening the matrix of the iron itself, so that an iron may be really harder to machine in consequence of having silicon added to it than it would have been with a somewhat smaller amount. There seems to be a certain probability, also, that the portion of the silicon burned out when the iron is melted in the cupola (about 0.25 per cent. in ordinary practice) remains to some extent enmeshed in the iron, and gives rise to that bane of the foundryman's existence—" dirty spots " —in the casting. These, being in the form of silica or silicate of iron, are, of course, very hard, and vastly increase the difficulties of machining the casting which contains them, even though they may not be present in sufficient amount to cause the rejection of the piece. The effect of silicon on the strength of the iron is, of course, very different in different portions of the silicon range. The amount which converts the iron from white to dense gray increases its strength by turning brittle and crystalline cementite into tough and homogeneous pearlite, even though the latter be somewhat cut up by graphite. But as the silicon content rises further and forces the combined carbon far below the pearlite ratio (say from 0.9 down to 0.2) it weakens the matrix and simultaneously increases the deposition of graphite and the size of its particles, interrupting the continuity of the structure, and in both these ways reducing the strength of the iron.

SULPHUR.

This is the most troublesome element in the metallurgy of iron. It is present in the coke with which irons are smelted, in amount from about 0.8 per cent. up to 2 per cent. Probably in present practice it averages 1.10 per cent. Most of this is forced into the slag, but sulphur has an affinity for iron, and it is commercially impossible in coke practice to maintain the sulphur continuously much below 0.025 per cent. in ordinary iron, and only down to that amount at excessive cost in coke and limestone over that required to hold it down to 0.04. Charcoal is almost free from sulphur, and, therefore, irons with one-half this sulphur *may* be made with that fuel more easily than iron with 0.025 per cent. can be made with coke. At the same time, charcoal iron does not average below 0.018 and is seldom below 0.010. This matter has been subject to very wide misapprehension, which has been a hurt and not a help to charcoal iron. The low sulphur of charcoal iron has often been claimed as its principal virtue. With sulphur contents claimed to be " a trace " or " under 0.01 per cent." the latter statement is totally erroneous, since the sulphur in practically all charcoal iron is twice the amount claimed, and is little or no lower than that of a great deal of coke iron, while the increase in sulphur in remelting in the cupola is so much greater than that in good iron of either kind that a far greater improvement as regards this element can, in general, be produced in the final product by a little more care in buying and analyzing the coke for the cupola, rather than the pig iron. The real virtue of charcoal iron is to be found in a totally different direction, as I shall presently endeavor to point out. Its freedom from sulphur gives charcoal the advantage which it enjoys in producing iron of higher quality than can be produced with coke, except by treatment after it leaves the furnace, but the low sulphur of the iron itself is not the reason for this superiority.

Sulphur forms with iron a sulphide which has an extremely low melting-point, and this sulphide dissolves in the iron itself in varying proportions in such a way that the sulphur exerts a threefold influence: *First,* it tends to hold the carbon in the combined condition. *Second,* it tends to liquate out into segregated spots, and, on account of its low melting temperature, sulphide of iron is extremely likely to bleed or run from the point which remains molten longest, and thereby cause a shrinkage cavity. *Third,* it has an objectionable tendency to produce high shrinkage in the iron with all the attendant difficulties of casting practice which accompany this condition.

Sulphur also has a very serious tendency to cause cracks in the iron, which is probably a result of the shrinkage. A white coke iron will often be high in sulphur, from 0.07 per cent. up to 0.2 or 0.3 per cent. in extreme cases. Such an iron, when quickly cooled with water, will crack up into little cubes like dice, each of whose faces is discolored almost black with a film of so-called " oxide color." White charcoal iron, on the other hand, of even lower silicon is tough and reasonably strong and practically never shows this tendency to break up into small pieces with oxidized faces. This statement is important and will bear some emphasis. In making coke iron low in silicon " basic " we always expected to see these conditions if the furnace became somewhat cold. On the other hand, in charcoal practice extending over three years I never recollect to have seen a single case of this, although the charcoal furnace, with the quickness of its kind, was capable of getting into just as serious difficulties as the coke furnace ever did, and did so much more frequently. Conditions are so similar in other respects that it seems to me we must assume that this objectionable tendency to form cracks is due to the presence of sulphur. In the manufacture of chilled cast-iron car wheels the sulphur must be kept within certain limits at all hazards, as otherwise the wheels will crack under the thermal test.

For this poison in the iron we have as antidotes silicon and manganese. The silicon has no tendency to remove the sulphur, but, tending as it does to force the graphitization of the carbon, it resists the tendency of the sulphur to keep it in the combined condition. There is a rough-and ready rule for the quantitative value of this effect, which is that 10 units of silicon are required to offset the effect of one of sulphur, so that, if the sulphur in the casting be raised 0.1 per cent., the silicon would require to be raised 1.0 per cent. to offset the sulphur. It is almost certain, however, that, while the silicon prevents the action of the sulphur on carbon, it does not prevent its tendency to produce cracks and to increase shrinkage, with all its attendant evils.

The ordinary sulphur specification for pig iron is 0.05 per cent. for steel-making irons, and 0.04 or 0.035 per cent. for foundry irons. For some special grades, for which a special price is paid, even lower limits are specified. When this iron is remelted in the cupola it always takes up some sulphur from the coke in the fuel bed; this amount varies from 0.02, in extra good practice, to 0.10 or even more, in bad practice, and, while I am not one of those who sneer at the foundrymen, it does seem that they are at times inconsistent, since many of them will make a violent protest if the sulphur in the pig is 0.01 per cent. higher than the specifications call for, and will then buy a cheap coke which will raise it 0.05 per cent. higher than would a really first-class coke. I regard sulphur as the most objectionable element in cast iron with which we have to contend, and I believe the foundrymen are absolutely right in leaving no stone unturned to get the sulphur as low as possible in their castings, but sometimes it seems that they put the emphasis in the wrong place. In this connection, it may be said that the benefits in holding down the sulphur, which may be obtained by the use of lime and a little fluor spar to flux the ash and sulphur of the coke, are not as widely appreciated as they should be.

PHOSPHORUS.

The determination of the effect of phosphorus upon steel might almost be said to have been the first fragment of our modern knowledge of metallurgy. You are perhaps familiar with the story that after Sir Henry Bessemer's first successful production of steel on an experimental scale he licensed manufacturers to use the process, but when they came to do so the product was rotten and worthless. His process was condemned, and he himself was subjected to contumely for his claims. He set out to find by chemical analysis the reason for the failure, and discovered that it lay in the phosphorus content of the iron from which the steel was made, and that, by one of those curious tricks of fortune, he had bought for his experiments the only iron in England low enough in phosphorus to make good steel. Once this was revealed, the ores which would produce iron of low enough phosphorus were located, and by using only these suitable iron for his process was obtained. With the exhaustion of the purer ores, the limit of the phosphorus set for Bessemer steel has gradually risen, until it is now about 0.09 per cent. Dozens of processes have been introduced for making good steel out of material containing more phosphorus than this without removing the latter, and it is said this may be done with some success so long as the carbon is low. When the carbon rises, however, such material always becomes brittle, uncertain, and unreliable. This has given phosphorus a bad name.

It has been assumed that because phosphorus was bad for steel it must necessarily be so for cast iron. Here again is found ignorance of that fundamental fact that a reduction of the strength of the matrix may be unimportant if a change in those conditions which affect its continuity is simultaneously made. Moreover, cast iron is a brittle material, and is not expected to be used in tension, or only under exceptional conditions, and there is no proof that phosphorus increases the brittleness of the metal until it reaches many times the limit permissible in steel. On the contrary, the Southern irons which carry in the neighborhood of 1.0 per cent. phosphorus command a premium for foundry purposes.

The effect of phosphorus is probably due to the fact that it forms one or more definite compounds with iron, which have a low melting-point, and which dissolve in the iron and lower the melting-point of the whole mass.[1] This is different from the effect of sulphur, in which the tendency seems to be for the last freezing portions to segregate after the major portion of material has solidified. The fact that phosphorus contributes to the fluidity of iron is well recognized, and for many classes of castings which require to be made very thin the phosphorus is run up to 1.0 per cent. or more. There is probably little doubt, however, that this content is high enough to affect the strength of the iron adversely. For general purposes, where strength is more and fluidity less important, phosphorus from 0.5 per cent. to 0.75 per cent. is to be preferred—the latter being only for lighter castings, the former for heavier and stronger castings.

---

[1] J. E. Stead, "Iron and Phosphorus," *Journal I. and S. Inst.*, 1900, ii.

(Since the above was written, I find that the experience of the automobile manufacturers has been that phosphorus must be kept below 0.3 per cent. in their extremely complicated and difficult cylinder castings, as more than this causes a slight liquation from the heavier parts of the castings to the lighter ones and produces porosity at the former points. Castings are more difficult to make with this low phosphorus content and have to be poured considerably hotter than would otherwise be necessary, but this is the only method by which porosity can be avoided. For the ordinary run of thin foundry work, where these very severe conditions do not have to be met, higher phosphorus facilitates the work greatly.)

The effect of phosphorus up to about 0.4 per cent. seems to be to increase the strength of iron. Remelts which I have made in crucibles proved this conclusively. Two remelts were made of the same iron, to one of which phosphorus was added, raising it from 0.13 to 0.40, the other not being changed in any way. This was done on two very different irons with the same result in both cases. The strength of the best bars was materially increased by the addition of the phosphorus, and so were the depth and character of the chill. These are both most desirable qualities for material such as car wheels, but the knowledge that somewhere below 1 per cent. phosphorus begins to make the metal brittle and treacherous debars us from going beyond very moderate limits in this direction for castings in which strength and reliability are the prime consideration.

OXYGEN.

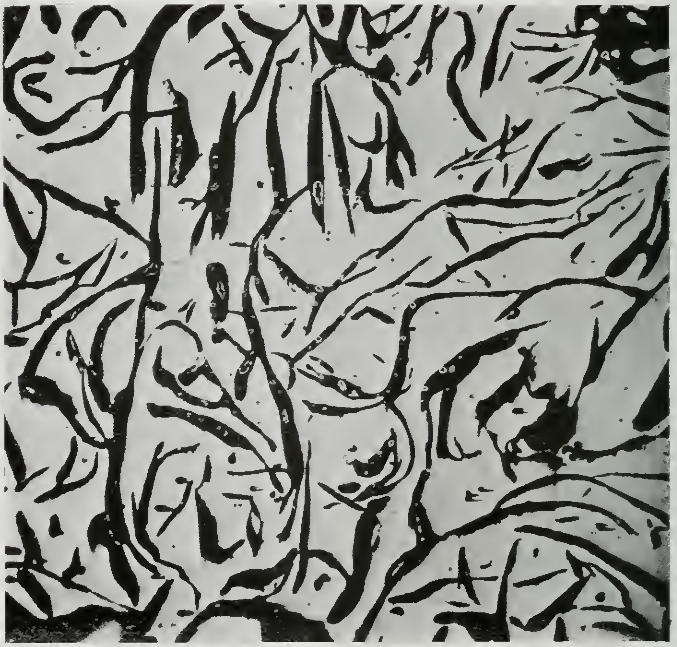
I come now to that portion of my subject in which I fear your credulity may be strained to the breaking-point. I have referred already to the investigation made at Ashland to determine the reason for the difference in quality of charcoal iron and coke iron. The first results of this investigation were those already described on the effect of high carbon, but, while these explained why some iron was bad, they did not explain why the irons of normal carbon were stronger than the coke irons of similar analysis, and in some cases very much stronger.

I went into the investigation with a profound conviction that, next to sulphur, oxygen was the worst enemy of cast iron, but, after several months spent in a vain endeavor to confirm this hypothesis, I suddenly conceived the idea that the *presence* of oxygen, and not its absence, was that which made charcoal iron superior to coke iron. Two years of research were required before sufficient proofs of this hypothesis to justify publication were secured, but these proofs were finally obtained and the results were published in a paper before the American Institute of Mining Engineers last winter, under the title " The Effect on the Strength of Cast Iron Exerted by Oxygen, Nitrogen, and Some Other Elements." The results of this investigation were at first violently combated by some scientific metallurgists, but are now being more and more accepted.

We found, first of all, that certain irons made when the furnace had been in trouble and working cold were exceedingly strong (sometimes, though not often, almost twice as strong as irons of practically identical analysis made at other times). We found that, after being remelted in crucibles, the strong ones retained and even increased their advantage in strength over the weak ones. We found, too, after months of trial, how to make oxygen determinations in cast iron; that the strong irons contained oxygen; that the weak irons contained little or none, and that those of normal moderate strength contained an intermediate amount. By a curious coincidence, a very extensive thermal investigation of the action of charcoal and coke blast furnaces was being simultaneously undertaken for the purpose of bettering the fuel economy if possible. This investigation revealed the fact that furnaces which produce the strong irons are those which run with a deficiency of heat in their hearths and so tend to an incomplete deoxidation of the ore,—that is, tend to leave a small amount of oxygen in the iron, while those furnaces which produce the weakest irons are those which generate the greatest excess of heat in the hearth and produce the metal at a temperature the highest of any above its melting-point, ending with the electric furnace, which develops practically all its heat in the hearth, and produces its iron at an excessively high temperature, this iron being the weakest of any variety of cast iron made. (See Figs. 10 and 11. Note the shape of the graphite and how it cuts the structure of the iron completely to pieces.)

Photomicrographs of different irons showed the reason for the increase in strength in the strong irons, since the graphite in these irons is relatively round and nodular compared with the graphite in the weak irons, which is thin and of tremendous extent, and cuts the iron like crooked knife strokes in all directions.

FIG. 10.



Unetched. (Magnified 100 diameters.) Electric furnace iron. Note extent and intersections of graphite. Strength of this iron very low, temperature of manufacture very high. Oxygen content zero.

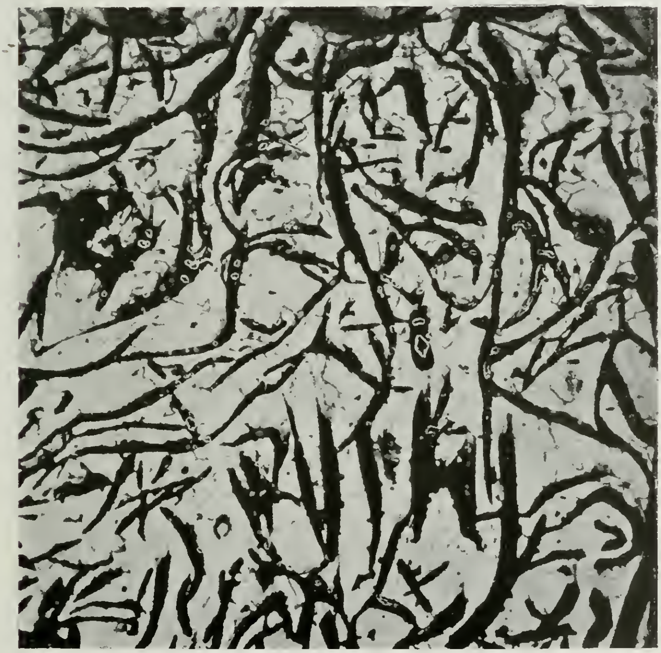
In Figs. 12 to 27 are shown strong irons and also weak irons of similar analysis, both before and after remelting. These figures are reproduced from the paper just mentioned. Figs 29 to 33 show in particular an extremely nodular condition of the graphite, and indicate more plainly than can any words how much stronger these irons must necessarily be than those of similar composition containing thin, flaky graphite.

The experiments described in the same paper, and briefly referred to here, are only a selection from the multitude of experiments, all pointing to the same conclusion, carried on throughout the investigation mentioned.

It seems that the effect of the oxygen is fivefold:

First, it tends to throw the graphite into the nodular condition. The theory as to the action by which this takes place has not yet been fully confirmed by scientific investigation, but coördinates so many facts that I am satisfied it is correct, and feel justified in pointing it out here. Observation has convinced me that the irons which contain oxygen have a higher melting-point than those which do not contain it. When approaching the freezing-point, they do not freeze suddenly, as water turns to ice, but pass through a slushy or pasty stage, very different from that of hot-made coke iron. When graphitization begins in the latter it is still liquid, and

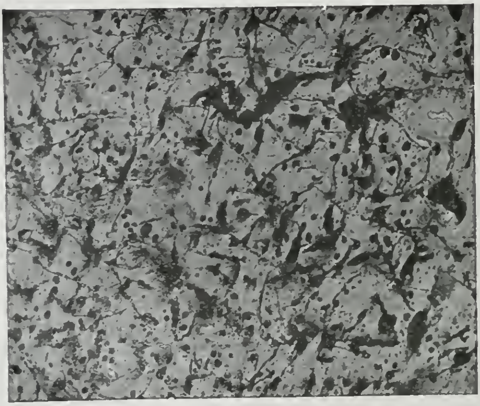
FIG. 11.



Etched. (Magnified 100 diameters.) Same as Fig. 10. Note complete absence of pearlite and joints in ferrite. These never occur in oxygen-bearing irons.

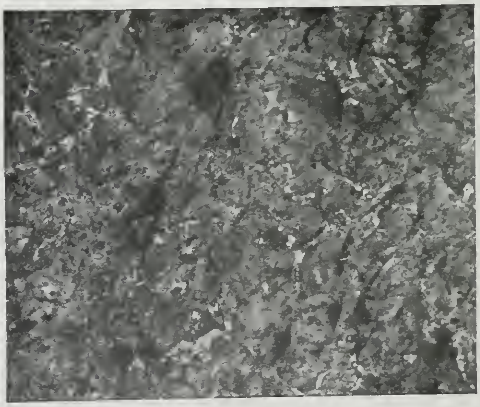
the graphite forms from the liquid absolutely without any stress whatever upon it, and is therefore free to assume whatever shape it chooses, irrespective of how great the volume and surface of that shape may be. But these oxygenated irons solidify at a higher temperature, at which little or no graphitization has yet taken place, and by the time they have cooled to the temperature of graphite evolution the iron matrix has become sufficiently solid to be the dominating element in the combination. The graphite forms, but forms only against the heavy pressure exerted by the

Fig. 12.



Unetched.

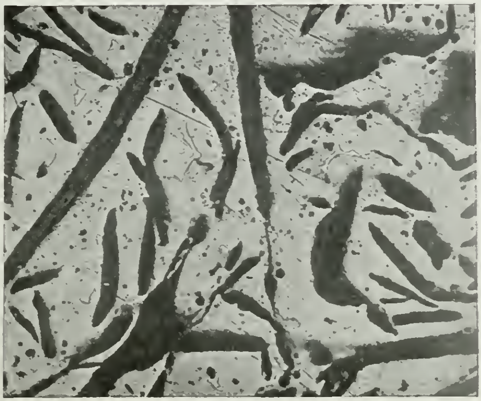
Fig. 13.



Etched. (Magnified 100 diameters.) Good iron. Silicon, 1.90; oxygen, 0.27 per cent. Breaking strength, 1.25-inch bar, 3000 pounds, 3350 pounds.

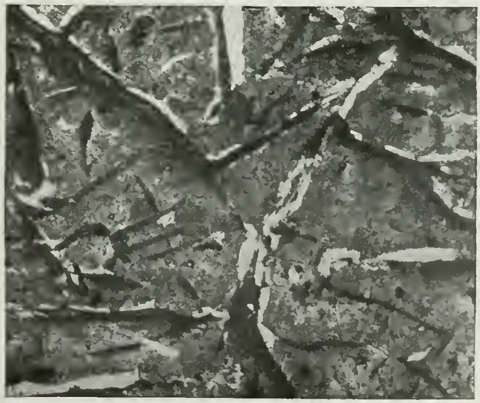
preformed solid of the metal. In consequence, the graphite must form so as to take up minimum volume and surface. In other words, it must take this spherical form in which it is seen in Figs. 26 to 31.

FIG. 14.



Unetched.

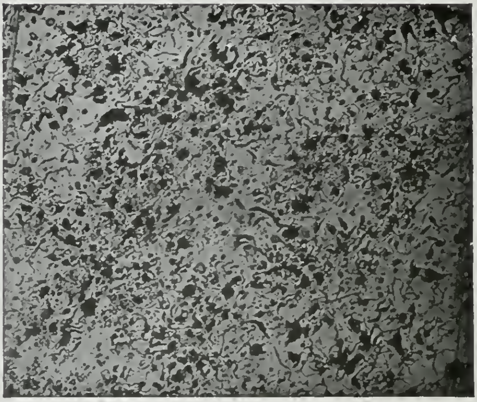
FIG. 15.



Etched. (Magnified 100 diameters.) Poor iron. Silicon, 1.88; oxygen, 0.009 per cent. Breaking strength, 1.25-inch bar, 2500 pounds, 2900 pounds.

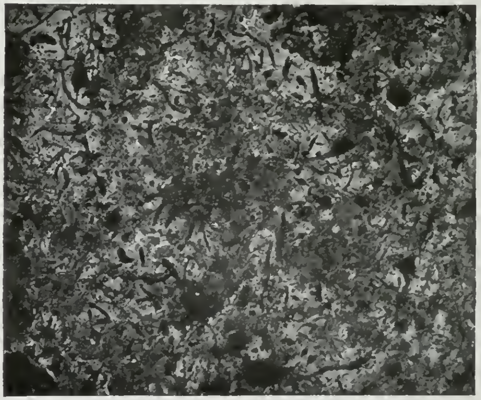
A confirmation of this theory is that good charcoal irons are noted for their low shrinkage, whereas bad ones are noted for their high shrinkage. This is, I believe, because when the graphite forms in the liquid, as it does in the oxygen-free irons, the iron then solidifies around it and after solidifying shrinks continuously until cold. But when the metal solidifies *previous* to the formation of graphite, the latter forms against the resistance of the metal, which results in an increase of volume of the latter after solidification, and this expansion is deducted from the total shrinkage in the final result. This theory is not absolutely demonstrated as yet, but it is certainly in accordance with all the facts and is well worthy of an investigation, which I hope will be undertaken by some of the scientific metallurgists within a year or two so as to confirm or refute it. Whatever may be the facts in regard to

FIG. 16.



Unetched.

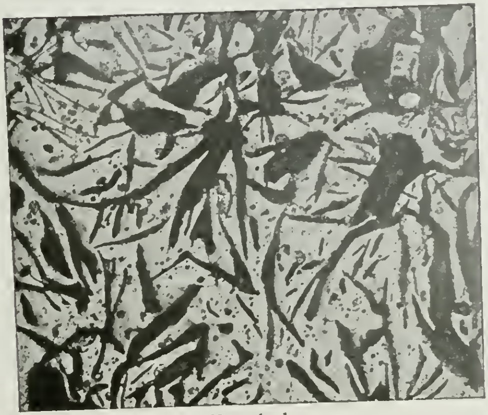
FIG. 17.



Etched. (Magnified 100 diameters.) Remelt. Silicon, 1.90 per cent. Breaking strength, 1.25-inch bar, 3150 pounds, 3200 pounds.

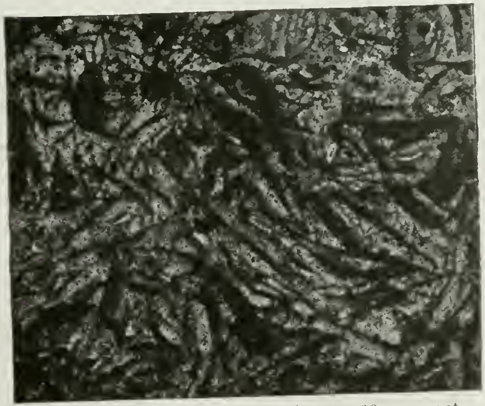
shrinkage, the increase in strength of irons which contain oxygen over those which do not contain it is a matter not open for discussion, nor is the shape into which it throws the graphite.

FIG. 18.



Unetched.

FIG. 19.



Etched. (Magnified 100 diameters.) Remelt. Silicon, 1.88 per cent. Breaking strength, 1.25-inch bar, 2600 pounds, 2700 pounds.

Second, the oxygen seems to exert another influence by changing the form of the crystallization of high carbon irons from that of the eutectic, previously shown in Fig. 3, to that of the meshwork structure, shown in Figs. 5 and 6. By this means it increases the strength of the matrix, as well as diminishes the detrimental action due to the graphite.

(*To be continued*)

Arc and Spark Spectra of Helium. J. STARK. (*Deutsch. Phys. Gesell. Verh.*, xvi, 10, 468.)—For a considerable time the author has investigated the difference between the arc and spark lines of elements in their canal- and cathode-ray emission, and has shown that the arc lines are emitted by the positive singly-charged atomions of the elements, while the spark lines are emitted by positive atomions doubly or multiply charged. The following results were obtained: (1) The line of wave-length 4686 Å., which has hitherto been considered a hydrogen line, is emitted strongly from the positive column of the oscillatory spark in helium free from hydrogen, so it must be assigned to helium. (2) The two known series systems of helium behave in the positive column, in cathode- and canal-rays, like arc lines. (3) The new helium line λ4686 behaves in the positive column, in canal-rays, like a spark line. (4) The peculiarities of the emission of the arc and spark spectra of helium can be explained by the fact that the former has for carrier the positive singly-charged helium atomion, the latter the positive doubly-charged atomion.

Epicassit. C. H. PROCTOR. (*The Metal Ind.*, xii, No. 11, 459.)—Epicassit is a recent German invention for coating iron or steel with pure tin, tin and lead, or a purely rust-free coating of tin, lead, and zinc. It is in the form of very finely powdered metal, mixed with an oil that acts as a flux. It is painted on the metal surface with a brush, and then the surface is heated until the applied metal melts, when it becomes thoroughly amalgamated with the surface metal, producing an extremely firm and durable coating. There are several alloys of epicassit, but the same oil flux is used for all.

A grade is pure Banca tin, free from lead.
B grade is two parts tin and one part lead.
C grade is two parts lead and one part tin.
C_1 grade is 95 per cent. lead and 5 per cent. tin.
E grade is 35 per cent. tin, 15 lead, and 50 zinc.

A Sentinel of Heat. ANON. (*Brass World*, x, No. 9, 350.)—For centuries the eye has been the judge of heat, as manifested in all its color forms, from dull red to dazzling white. Variable conditions of light and physical changes tend to render the operator's judgment inaccurate. The pyrometer and the heat cone are being used in place of the eye with profit and success. The Carl Nehls Alloy Company, 248 Brush Street, Detroit, Mich., has introduced into the field of heat measurement a small pyrometric cylinder, composed of molecular mixtures of metallic salts, known as the Sentinel pyrometer. These pyrometers can be made to melt at any desired temperature, but they solidify again if the temperature falls below that point. Two sentinels control a furnace within any desired limits of temperature, the one being liquid, while the other remains solid. Special data on heat measurements up to 2426° F. can be obtained by application for the literature of the company.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

A COMPARISON OF STELLAR RADIOMETERS AND RADIOMETRIC MEASUREMENTS ON 110 STARS.

By W. W. Coblentz.

In this paper experiments are described showing that there is but little difference in the radiation sensitivity of stellar thermocouples constructed of bismuth-platinum, and thermocouples of bismuth – bismuth + tin alloy, which have a 50 per cent. higher thermo-electric power.

Improvements are described in the method of maintaining a vacuum, by means of metallic calcium, whereby it will be possible to go to the remotest stations for making radiation measurements without carrying an expensive vacuum pump.

With this outfit measurements were made on the radiation from 112 celestial objects, including 105 stars. This includes measurements on the bright and the dark bands of Jupiter (also a pair of his satellites), the rings of Saturn, and a planetary nebula.

Quantitative measurements were made on stars down to the 5.3 magnitude, and high-grade qualitative measurements were made on stars down to the 6.7 magnitude.

It was found that red stars emit from two to three times as much total radiation as blue stars of the same photometric magnitude.

Measurements were made on the transmission of the radiations from stars and planets through an absorption cell of water. By this means it was shown that, of the total radiation emitted, the blue stars have about two times as much radiation as the yellow stars, and about three times as much radiation as the red stars, in the spectral region to which the eye is sensitive.

A stellar thermocouple and a bolometer were compared, and the former was found to be more sensitive. The conclusion arrived at is that, from the appearance of the data at hand, greater improvements are to be expected in stellar thermocouples than in stellar bolometers.

---

* Communicated by the Bureau.

The object of the investigation was to obtain some estimate of the sensitivity required in order to be able to observe spectral energy curves of stars. The radiation sensitivity of the present apparatus was such that, when combined with a 3-foot reflecting telescope, a deflection of 1 mm. would have resulted when exposed to a candle placed at a distance of 53 miles. In order, however, to do much successful work on stellar spectral energy curves, a sensitivity 100 times this value is desirable. In other words, assuming that the rays are not absorbed in passing through the intervening space, the radiometric equipment (radiometer and mirror) must be sufficiently sensitive to detect the radiation from a candle removed to a distance of 500 miles. This can be accomplished by using a 7-foot mirror and by increasing the sensitivity of the present radiometer (thermocouple and galvanometer) 20 times. This increase in sensitivity is possible.

Measurements were made to determine the amount of stellar radiation falling upon 1 cm^2 of the earth's surface. It was found that the quantity is so small that it would require the radiations from *Polaris* falling upon 1 $cm.^2$ to be absorbed and conserved continuously for a period of 1,000,000 years in order to raise the temperature of 1 gramme of water 1° C. If the total radiation from all the stars falling upon 1 $cm.^2$ were thus collected and conserved it would require from 100 to 200 years to raise the temperature of 1 gramme of water 1° C. In marked contrast with this value, the solar rays can produce the same effect in about one minute.

THE TEMPERATURE COEFFICIENT OF MAGNETIC PERMEABILITY WITHIN THE WORKING RANGE.

By Raymond L. Sanford.

[ABSTRACT.]

MAGNETIC measurements at different temperatures within the atmospheric range were made on wrought iron, cast iron, and low carbon steel with different heat treatments. The results of these measurements seem to warrant the following conclusions:

1. The temperature coefficient of magnetic permeability, though

small, cannot be neglected in magnetic measurements of high accuracy.

2. On account of the wide variation in temperature coefficient, not only for different materials, but also for the same material with different heat treatments, correction cannot be made to standard temperature from data obtained from other materials.

3. Unless the temperature coefficient is known for the particular material under test, temperature control offers the only means of avoiding the error due to temperature changes, at least where errors as great as 1 per cent. are to be avoided.

CHARACTERISTIC EQUATIONS OF TUNGSTEN FILAMENT LAMPS AND THEIR APPLICATION IN HETEROCHROMATIC PHOTOMETRY.*

By G. W. Middlekauff and J. F. Skogland.

THE most difficult problem in ordinary photometry is the comparison of the intensity of light sources differing widely in color. In such comparisons it is practically impossible, even for the most experienced observers, to agree in their measurements, this disagreement being due principally to difference in color vision and to difference in judgment as to when two colors viewed in the photometer are of equal intensity. Hence, especially, to establish standards, a large number of observations by different experienced observers must be taken to average out the personal errors.

One of the most convenient methods of avoiding color difference in practical photometry is by the use of colored glasses to bring the lamps to a color match; but by this method the principal difficulties are merely shifted to the problem of calibrating the glasses, a large number of which are necessary to meet the present requirements of colored light photometry.

By the method described in this paper, color differences are avoided by the use of tungsten standard lamps which are adjusted in voltage to color-match the light source to be measured, and the candlepower values of the standards at the voltage corresponding to that color are computed from the voltage at which the candlepower is known, this computation being made by the use of the voltage-candlepower equation of the standards.

---

* Abstract of Scientific Paper No. 238.

In order to fully realize the advantages of this method in practice, it was necessary, first, to measure a large variety of tungsten lamps to find the relation of candlepower to voltage, and then to calculate the equation which would express this relation over a wide range of voltage or efficiency. The results were far more satisfactory than was at first anticipated.

It was found that all vacuum tungsten lamps, within a wide range of wattage, have the same voltage-current-candlepower characteristics, regardless of the make or method of manufacture. It was found, also, that not only the voltage-candlepower relation, but also the voltage-current, voltage-wattage, and voltage-watts per candle relations, could be accurately expressed by one general equation of the form $y = Ax^2 + Bx + C$. In this equation x = log voltage, y = log candlepower, log wattage, log current, or log watts per candle, and A, B, and C are constants, the values of which depend upon the significance of y. It is found most convenient to express all these variables, except watts per candle, in terms of the respective values of each at a chosen normal efficiency. In this way the constant C disappears from the equation except when y represents the watts per candle, in which case C is the log of the watts per candle chosen as normal.

The above general equation applies very exactly over the whole range investigated, namely, from 0.7 wpc. to 3.3 wpc., the latter limit extending somewhat beyond the watts per candle corresponding to color-match with 4-wpc. carbon lamps.

These equations are useful for two purposes. The international candle is maintained at the Bureau of Standards by means of 4-wpc. carbon standard lamps. If, for example, it is desired to establish a group of tungsten standards operating at 1.5 wpc., these tungsten standards would be measured directly in terms of the primary 4-wpc. carbon standards, with the voltage on the tungsten lamps so adjusted as to bring them into color-match with the primary standards. Then, knowing the voltage and corresponding efficiency of the tungsten lamps at this color, the voltage, current, watts, and candlepower corresponding to an efficiency of 1.5 wpc. are computed by means of the above characteristic equations.

Another use of these equations is in connection with tungsten standards the values of which are known at some particular efficiency (or color). In standardizing other lamps these standards are adjusted to a color-match with the lamps to be measured, and the values of candlepower, current, etc., for each standard, at the voltage corresponding to that particular color, are determined by means of the characteristic equations.

Although these equations are simple and easy to handle, their use involves comparatively long and tedious computations. To avoid the necessity of making such computations, there has been computed and appended to the paper a set of tables from which, with the aid of an ordinary slide rule, correction factors to reduce values of candlepower, current, etc., from one efficiency to another may be read directly.

By the method described above, the photometric difficulties due to color difference are dealt with, once for all, in determining the characteristics of the tungsten lamp, and thereafter all measurements are reduced to the photometry of lights of the same color.

Copper Production in Japan. ANON. (*Metal Ind.*, xii, No. 10, 424.)—Copper is the most important mineral product of Japan. Its production has been increasing for many years in a steady ratio to the number and growing efficiency of the plants. The year 1913 was not favorable for copper mining, the prices throughout the world fluctuating so that producers were unable to foresee market conditions. Nevertheless, the production of copper in Japan increased by 3410 metric tons in 1913 over the previous record of 61,471 tons in 1912. The value of the copper production in 1912 was $20,045,526, and in 1913, $20,716,800. The greater part of the ore mined in Japan is smelted at the mines and exports in 1912 and 1913 were less than $1000.

New Flashlight Powder. ANON. (*Sci. Amer.*, cxi, No. 13, 243.)—Flashlight powders for photographic use are generally made up of magnesium, combined with a substance rich in oxygen, such as potassium chlorate, but the great drawback of such powders is that they occasion considerable smoke or fumes. Efforts made by European inventors to find a photographic powder that gives but little smoke have proved successful, and the new "Excelsior" compound uses magnesium and oxygen-bearing substances coming from the rare earths. Lanthanum peroxide was chosen, and substances were added to it analogous to those used in Welsbach lamp mantles. These form a powder giving an excellent flashlight and only one-tenth the amount of smoke, which immediately dissipates.

Cathodic Spattering of Metals. G. W. C. KAYE. (*Proc. Phys. Soc.,* xxv, part iii.)—Cathodic spattering observed when a current is sent through a discharge tube at low pressures, and resulting in the deposition of metal on the glass adjacent to the cathode, has proved very useful as a means of preparing films and mirrors, especially in the case of metals intractable by the usual methods. The spattered metal is expelled from the cathode as minute particles, apparently of the same order of magnitude as those present in colloidal solutions; they settle only on surfaces positive with respect to the cathode, and in practice the surface to be coated is connected with the anode. With certain exceptions, the amount of spattering is roughly proportional to the chemical equivalent of the metal. The effect is usually marked with palladium, platinum, gold, silver, copper, cadmium, and tin, but is small in the case of aluminum and iron in air. With cadmium and zinc a rise of temperature of the cathode greatly increases the effect. The amount of spattering is roughly proportional to the square of the current density, and is increased by increasing the potential drop at the cathode,—*e.g.*, by diminishing the pressure of the gas in the tube. Hydrogen, nitrogen, and carbon dioxide act unfavorably. Mercury vapor, oxygen, and more especially the monatomic gases, helium, neon, argon, krypton, and xenon, effect marked spattering of nearly all metals, argon being particularly effective. The appearance and properties of the deposit depend upon the nature of the gas. The spattering is usually confined mainly to points and edges of the cathode, where the potential gradient attains a maximum, and it is suggested that the blackening of X-ray tubes might be largely prevented by constructing the cathode wholly free from sharp edges and the anti-cathode of approximately spherical shape.

Novel Wax Bleaching Plant. ANON. (*Sci. Amer. Supple.,* lxxviii, No. 2015, 105.)—A novel wax bleaching plant at Brentford, England, consists essentially of an electrically driven blower, an air cooler, a battery of five ozonizers, and the vessel in which the material is treated. The ozone produced is led to the bottom of the treating vessel, and passes up through the liquid, molten wax in fine jets, which effect the bleaching.

Lead-pencil Comparison Spectrum. J. LUNT. (*Cape of Good Hope Observatory,* Ann. 10.)—For the study of many terrestrial and celestial spectra it is often necessary to arrange for a comparison spectrum capable of furnishing certain standard lines for the reduction. A convenient source for this has been found in the graphite of an ordinary lead pencil, which generally contains sufficient impurities to give lines of iron, titanium, vanadium, chromium, barium, strontium, calcium, and often gallium, scandium, yttrium, silicon, magnesium and manganese, in addition to the carbon.

THE FRANKLIN INSTITUTE

(*Proceedings of the Stated Meeting held Wednesday, December 16, 1914.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 16, 1914.

VICE-PRESIDENT COLEMAN SELLERS, JR., *in the Chair.*

Additions to membership since last report, 6.

Mr. George R. Henderson, Chairman of the Committee on Science and the Arts, reported the condition of the committee's work.

The following nominations were made for officers and managers to be voted for at the annual election to be held January 20, 1915:

For President (to serve one year), Walton Clark.

For Vice-President (to serve three years), James M. Dodge.

For Treasurer (to serve one year), Cyrus Borgner.

For Managers (to serve three years), J. J. Gibson, Charles Day, George A. Hoadley, Isaac Norris, Jr., Lawrence T. Paul, James S. Rogers, George R. Henderson, and Alfred W. Gibbs.

The Chairman then introduced Dr. William Barclay Parsons, of New York City, who presented an interesting communication, entitled "An American Engineer in China." Discussing China as a field for engineering developments, Dr. Parsons described the transportation facilities of the country, and also its mineral wealth and other natural resources. He gave an account of the work done up to the present time to extend and improve transportation and to develop and utilize the natural resources. In connection with further extension to this field of development, he outlined the methods of law, finance, and construction to be taken into account. He concluded with a description of some further work, in his opinion, immediately necessary. During the course of his remarks he related numerous anecdotes and personal experiences. The subject was well illustrated by lantern slides from original photographs. A rising vote of thanks was extended to the speaker.

Adjourned.

R. B. OWENS.
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, December 2, 1914.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 2, 1914.

MR. J. A. P. CRISFIELD, *Chairman pro tem.*

The following reports were presented for first reading:

No. 2614.—Hardinge Conical Pebble Mill. (Further consideration.)
No. 2624.—Vanier's Potash Bulb.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A stated meeting of the Section was held in the Hall of the Institute on Thursday, December 3, 1914, at 8 o'clock P.M., with Dr. Harry F. Keller in the chair. The minutes of the previous meeting were read and approved.

A. S. Eve, D.Sc., Professor of Physics in McGill University, Montreal, Canada, delivered a lecture entitled "Modern Views on the Constitution of the Atom." The evidence concerning the interior of the atom, as given by the collisions of alpha particles with molecules, by the crystal reflection of Röntgen and gamma rays, and by modern radiochemistry, was discussed, as were Planck's quantum and Bohr's speculations. The lecture was illustrated with lantern slides and charts and by means of experiments. A vote of thanks was extended to Dr. Eve, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary,

Mechanical and Engineering Section.—A meeting of the Section was held in the Hall of the Institute on Thursday, December 10, 1914, at 8 P.M. Mr. Charles Day presided. The minutes of the previous meeting were approved as published.

The Chairman introduced Mr. R. H. M. Robinson, Managing Director of the Lake Torpedo Boat Company, Bridgeport, Conn., and formerly Naval Constructor, U. S. N., who presented a communication entitled "The Modern Submarine in Naval Warfare."

The speaker considered in some detail the power, radius of action, and armament of submarine vessels, and the degree of invulnerability of battleships against submarine attack. He outlined the tactics of submarines, considering the methods of signalling between them and other units of a fleet. He stated his belief in the necessity of two types of submarines, one for defensive use at home and the other for sea-going purposes to accompany the fleet and take part in offensive actions.

At the close of Mr. Robinson's remarks, Captain W. S. Benson, U. S. N., gave his opinion of the number of submarines required by a navy and of the manner in which they should be used.

A vote of thanks was extended Mr. Robinson, and the meeting adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, December 9, 1914.*)

RESIDENT.

MR. J. A. CAPSTAFF, New York Shipbuilding Company, Camden, N. J.
MR. CHARLES W. G. KING, 429 North Thirteenth Street, Philadelphia, Pa.
PROFESSOR HAROLD PENDER, University of Pennsylvania, Philadelphia, Pa.

COLONEL HARRY C. TREXLER, Allentown, Pa.
MR. CHARLES W. YOUNG, 1255 North Twenty-sixth Street, Philadelphia, Pa.

NON-RESIDENT.

MR. ERNEST L. HUFF, Natrona, Pa.

CHANGES OF ADDRESS.

MR. ROBERT BIDDLE, 3846-48 Lancaster Avenue, Philadelphia, Pa.
MR. CASPAR WISTAR HAINES, 6026 Germantown Avenue, Philadelphia, Pa.
MR. WALTER PALMER, 120 East Twenty-third Street, Chester, Pa.
MR. W. N. RUMELY, Sycamore, Ill.
MR. H. E. TROTMAN, 722 Washington Street, Camden, N. J.

NECROLOGY.

William Booth Bryan was born at Nottingham, England, in 1848. He was articled to a civil engineer of that city, and acted afterwards as assistant engineer to the Corporation of Nottingham and also to the Nottingham and Leen Valley District Sewerage Board. In 1873 he was appointed engineer to the Corporation of Burnley, and in this capacity he designed and carried out a complete sewage scheme and other important public works. Two years later he became borough and water engineer to the Corporation of Blackburn, and was responsible for the building of viaducts and bridges and for the design of a new water supply for that city. Before this latter work was completed, he was appointed, in 1882, chief engineer to the East London Water Company. He continued in this capacity until 1904, and his efforts in connection with the purification of the company's supply resulted in a considerable lowering of the typhoid death-rate in the East End of London. During his service the number of houses connected to the company's mains was practically doubled.

Mr. Bryan was elected to membership in the Institution of Civil Engineers in 1875, and was appointed a member of its Council in 1908. He was president of the Junior Institution of Engineers in 1907. He became a member of The Franklin Institute in 1902.

LIBRARY NOTES.

PURCHASES.

American Institute of Chemical Engineers.—Transactions, vol. 6. 1913.
ASCH, W. and D.—Silicates in Chemistry and Commerce. 1913.
COLQUHOUN, A. R.—Key to the Pacific—the Nicaragua Canal. 1895.
ELLIS, CARLETON.—Hydrogenation of Oils, Catalyzers and Catalysis. 1914.
HARLOFF, W. H. T., and SCHMIDT, H.—Plantation White Sugar Manufacture. 1913.

Jahrbuch der Chemie, Jahrgang 23. 1913.

JONES, HARRY C.—Freezing-point, Boiling-point, and Conductivity. 1912.

KOPPESCHAAR, EDWARD.—Evaporation in the Cane and the Beet Sugar Factory. 1914.

PARRY, ERNEST J.—Chemistry of Essential Oils and Artificial Perfumes. 1908.

PENDER, HAROLD, ed.—American Handbook for Electrical Engineers. 1914.

RIES, H., and WATSON, T. L.—Engineering Geology. 1914.

SCUDDER, HEYWARD.—Electrical Conductivity and Ionization Constants of Organic Compounds. 1914.

SIMPSON, GEORGE.—The Naval Constructor—the *Vade Mecum* of Ship Design. 1914.

SINDALL, R. W.—Paper Technology, ed. 2. 1910.

SINDALL and BACON.—Testing of Wood Pulp. 1912.

STILLMAN, THOMAS B.—Examination of Lubricating Oils. 1914.

GIFTS.

Allen, Edgar & Company, Limited, Catalogue of Tool Steel, Files, Saws, etc. Sheffield, 1914. (From the Company.)

American Art Marble Company, Catalogue of American Art Marble. Philadelphia, no date. (From the Company.)

American Institute of Electrical Engineers, vols. xiii–xvi. New York, 1897–1900. (From Mr. C. W. Pike.)

American Radiator Company, "The Ideal Fitter." Philadelphia, no date. (From the Company.)

American Society for Testing Materials, Proceedings. Philadelphia, 1914. (From the Secretary-Treasurer.)

American Society of Civil Engineers, Transactions. New York, 1914. (From the Society.)

Amsterdam Koninklijke Akademie van Wetenschappen, Jaarboek. Amsterdam, 1913. (From the Academy.)

Amsterdam Royal Academy of Sciences, Proceedings of the Section of Sciences, vol. xvi, parts 1 and 2. Amsterdam, 1913. (From the Academy.)

Arrow Electric Company, Catalogue No. 16. New York, 1913. (From the Company.)

Atlas Portland Cement Company, Catalogue of Non-Staining Portland Cement. Chicago, no date. (From the Company.)

Baylor University, Annual Report of the President and Trustees. Waco, 1914. (From the University.)

Belden Manufacturing Company, Catalogue No. 6. Chicago, 1914. (From the Company.)

Bliss, E. W. Company, Catalogue of Presses. New York, 1914. (From the Company.)

Brown & Sharpe Manufacturing Company, Catalogue No. 20–G. Providence, no date. (From the Company.)

Caldwell, H. W. & Son Company, Catalogue No. 38. Chicago, no date. (From the Company.)

Canada Department of Mines, Memoirs 41 and 54; Museum Bulletins Nos. 3, 4, and 5. Ottawa, 1914. (From the Department.)

Carpenter Steel Company, Catalogue D. Reading, no date. (From the Company.)

Goodell-Pratt Company, Catalogue No. 11. Greenfield, 1913. (From the Company.)

Graton & Knight Manufacturing Company, "Belting Manual." Worcester, no date. (From the Company.)

Great Britain Board of Trade, Report on Strikes and Lock-Outs, 1913. London, 1914. (From the Board of Trade.)

Hartmann, Carl, Praktisches Handbuch der Stahlfabrikation. Weimar, 1861. (From Mr. Henry Hess.)

Hobart College, Catalogue of William Smith College. Geneva, 1914. (From the College.)

Illinois State Geological Survey, Bulletin No. 28. Urbana, 1914. (From the Survey.)

Illinois Stoker Company, Catalogue of Chain Grate Stokers. Alton, no date. (From the Company.)

Illinois Water Survey, Report, 1913, Series 11. Urbana, 1914. (From the University of Illinois.)

Industrial Works, Book No. 107. Bay City, no date. (From the Company.)

Johns-Manville, H. W. Company, Catalogues of Fuses and Accessories. Philadelphia, no date. (From the Company.)

Kansas City Southern Railway Company, Fourteenth Annual Report. New York, 1914. (From Mr. Charles A. Thress.)

Karsten, C. J. B., Handbuch der Eisenhüttenkunde, parts 1–5. Berlin, 1841. (From Mr. Henry Hess.)

Kennedy Valve Manufacturing Company, General Catalogue. Elmira, 1915. (From the Company.)

Kerl, Bruno, Handbuch der metallurgischen Hüttenkunde, vol. iii, and Atlas. Leipzig, 1864. (From Mr. Henry Hess.)

Kissel Motor Car Company, Catalogue of Trucks. Hartford, no date. (From the Company.)

Link-Belt Company, Books Nos. 124 and 158. Philadelphia, no date. (From the Company.)

Lunkenheimer Company, Catalogue No. 50. Cincinnati, 1912. (From the Company.)

Champion Rivet Company, Catalogue. Cleveland, 1914. (From the Company.)

Chelten Electric Company, Catalogue of Electrical Specialties. Philadelphia, 1915. (From the Company.)

Chicago Belting Company, Catalogue. Chicago, no date. (From the Company.)

Chicago, Rock Island and Pacific Railway Company, Thirty-fourth Annual Report. New York, 1914. (From the Company.)

Clay Product Company, The A, B, C of Good Building. Chicago, no date. (From the Company.)

Cleveland Twist Drill Company, Catalogue No. 38. Cleveland, 1914. (From the Company.)

Clinton Wire Cloth Company, Successful Stucco Houses. Clinton, no date. (From the Company.)

Colgate University, Catalogue, October. Hamilton, 1914. (From the University.)

Consolidated Press and Tool Company, Catalogue No. 10. Hastings, no date. (From the Company.)

Cyclone Drill Company, Catalogue No. H-30. Orrville, no date. (From the Company.)

de Saunier, L. B., Das Automobil in Theorie und Praxis, vol. ii. Vienna, 1901. (From Mr. Henry Hess.)

Diamond Chain and Manufacturing Company, Treatise on Power Chains and Sprockets. Indianapolis, no date. (From the Company.)

Eck Dynamo and Motor Company, Bulletin No. 39. Belleville, no date. (From the Company.)

Ferracute Machine Company, Catalogue No. 20. Bridgeton, no date. (From the Company.)

Fibre Conduit Company, Catalogue of Conduits. New York, no date. (From the Company.)

Finland, Suomen Teollisuushallituksen Tiedonantoja, 1912; Arbetsstatistik A-1910; Yrkesinspektorernas, 1912; Teollisuustilastoa, 1912; Helsingissa, 1914. (From the Patent Office of Finland.)

Mechanical Rubber Company, Perpetual Catalogue. Cleveland, no date. (From the Company.)

Morris Machine Works, Catalogue of Centrifugal Pumps. Baldwinsville, 1913. (From the Company.)

Morse Twist Drill and Machine Company, Catalogue of Twist Drill Machinery. New Bedford, 1915. (From the Company.)

Napoli, R., Istituto d'Incoraggiamento, Atti 1913. Napoli, 1914. (From the Institute.)

National Electric Light Association, Thirty-seventh Convention. New York, 1914. (From the Association.)

Ontario Bureau of Mines, Twenty-third Annual Report. Toronto, 1914. (From the Bureau.)

Peabody Institute of the City of Baltimore, Forty-seventh Annual Report. Baltimore, 1914. (From the Institute.)

Peck Drop Press Works, Catalogue of Drop Presses. New Haven, no date. (From the Company.)

Pennsylvania Adjutant-General, Report, 1909. Harrisburg, 1914. (From the State Librarian.)

Pennsylvania Culpeper (Virginia) Monument Commission, Report. Harrisburg, 1914. (From the State Librarian.)

Pennsylvania Department of Labor and Industry, Labor Laws of Pennsylvania. Harrisburg, 1914. (From the State Librarian.)

Pennsylvania Fire and Marine Insurance, Forty-first Report, 1913. Harrisburg, 1914. (From the State Librarian.)

Pennsylvania Life Insurance Commission, Forty-first Report, 1913. Harrisburg, 1914. (From the State Librarian.)

Pennsylvania Railroad Company, Pamphlets E-1, E-2, E-3, E-4, M-1, M-1-A, M-1-B, M-3, O, Q-1, A-1. Philadelphia, no date. (From the Superintendent of Telegraphs.)

Pennsylvania Water Supply Commission, Reports. Harrisburg, 1910, 1914. (From the State Librarian.)

Pere Marquette Railroad Company, Annual Report. Detroit, 1914. (From the Company.)

Philadelphia Bureau of Surveys, Annual Report, 1913. Philadelphia, no date. (From the Bureau.)

Ransome Concrete Machinery Company, Catalogues. Dunellen, no date. (From the Company.)

Reeves-Cubberley Engine Company, Catalogue No. 17. Trenton, 1914. (From the Company.)

Royal Society of Arts, History of the Society. London, 1913. (From Sir Henry Trueman Wood.)

Ryerson, Joseph T. & Son, Morison Suspension Furnaces for Internal Furnace Boilers. Chicago, 1912. (From the Company.)

Smith College, Catalogue. Northampton, 1914. (From the College.)

Smithsonian Institution, Physical Tables, sixth edition. Washington, 1914. (From the Institution.)

Southern Pacific Company, Thirtieth Annual Report. New York, 1914. (From the Treasurer.)

Stephens-Adamson Manufacturing Company, Catalogue No. 19, Sections 3 and 4. Aurora, no date. (From the Company.)

Stowe-Fuller Company, Catalogue of Fire Brick. Cleveland, no date. (From the Company.)

Strong, Carlisle & Hammond Company, Catalogues Nos. 5 and 18. Cleveland, no date. (From the Company.)

Thomas, Arthur H. Company, Laboratory Apparatus and Reagents. Philadelphia, 1914. (From the Company.)

Travelers Indemnity Company, Catalogue, Boiler Economy. Hartford, 1913. (From the Company.)

Travelers Insurance Company, Two pamphlets: Safety in Moving-picture Theatres and Foremen and Accident Prevention. Hartford, 1914. (From the Company.)

Tyler, W. S. Company, Catalogue No. 40. Cleveland, no date. (From the Company.)

U. S. Secretary of Commerce, Annual Report. Washington, 1914. (From the Secretary.)

University of Wisconsin, Thirtieth Annual Report of Agricultural Experiment Station. Madison, 1913. (From the University.)

Wellington Glass Company, Catalogue No. 3. Cumberland, no date. (From the Company.)

Western Australia Geological Survey, Bulletins Nos. 48, 51 (parts 1 and 2), 52, 53, 54. Perth, 1914. (From the Agent-General.)

BOOK NOTICES.

Food Industries, An Elementary Text-Book on the Production and Manufacture of Staple Foods, by Herman T. Vulté, Ph.D., F.C.S., and Sadie B. Vanderbilt, B.S. Easton, The Chemical Publishing Company, 1914. 287 pages, illustrations, 8vo. Price, $1.75.

This is a well-printed and well-illustrated work, presenting in attractive form information concerning many of the organized industries employed in preparing raw food materials for use. After about ten pages on general questions, information is given concerning water, cereals, including methods of milling, bread-making leavening agents, starch, sugars, alcoholic beverages, the several classes of foods, and special chapters on such important foods as milk and milk products, meats, and the materials used in the cups that "cheer but not inebriate." Illustrations of apparatus and large-scale installations are freely used, so that the pupil will obtain a good idea of modern American methods in the food industries.

Evidently much close study has been given by the authors in the collection of data, and general accuracy has been secured, but on page 173 serious errors occur in reference to the effect of storage on whiskey. It is there stated that by such storage whiskey loses its fusel oil and its toxicity. The investigations of Crampton and Tolman, published some years ago, have shown that no appreciable change in the amount of fusel oil takes place even in several years' storage. The facts in regard to this matter should be set forth clearly in subsequent editions of this work.

Henry Leffmann.

PUBLICATIONS RECEIVED.

Optic Projection: Principles, Installation, and use of the Magic Lantern, Projection Microscope, Reflecting Lantern, Moving-picture Machine, by Simon Henry Gage, professor of histology and embryology, emeritus, Cornell University, and Henry Phelps Gage, Ph.D. 731 pages, illustrations, 8vo. Ithaca, N. Y., Comstock Publishing Company, 1914. Price, $3.

Automatic Telephony: A Comprehensive Treatise on Automatic and Semi-automatic Systems, by Arthur Bessey Smith, E.E., and Wilson Lee Campbell, E.E. 407 pages, illustrations, plates, 8vo. New York, McGraw-Hill Book Company, 1914. Price, $4.

University of Illinois Bulletin, vol. ii, No. 38, Water Survey Series No. 11, Chemical and Biological Survey of the Waters of Illinois, report for the year ending December 31, 1913. Edward Bartow, director. 478 pages, illustrations, 8vo. Urbana, University, 1914.

Mellon Institute of Industrial Research and School of Specific Industries, Smoke Investigation Bulletin No. 9, Papers on the Influence of Smoke on Health, edited by Oskar Klotz and William Charles White. 173 pages, illustrations, plates, 8vo. Pittsburgh, University of Pittsburgh, 1914. Price, 50 cents.

Ontario Bureau of Mines, Twenty-third Annual Report, 1914, being volume 23. 339 pages, illustrations, plates, maps, 8vo. Toronto, King's Printer, 1914.

British Fire Prevention Committee, Red Book No. 190, The Committee's Record for the Year 1913, the Committee's Christmas Warnings, Safeguards for School Entertainments, Inflammable Materials for Costumes and Decorations, Celluloid Dangers, Flannellete Dangers, Portable Chemical Fire Extinguishers, Self-contained Smoke Helmets, the Committee's Enquiry Office. 40 pages, illustrations, 8vo. London, British Fire Prevention Committee, 1914. Price, two shillings and six pence.

New York Public Library, List of Works in the Library Relating to Oxy-acetylene Welding. 34 pages, 8vo. New York, 1914.

U. S. Bureau of Mines: Bulletin 85, Analyses of Mine and Car Samples of Coal Collected in the Fiscal Years 1911 to 1913, by Arno C. Fieldner, Howard I. Smith, Albert H. Fay, and Samuel Sanford. 444 pages. Monthly Statement of Coal-mine Fatalities in the United States, September, 1914, compiled by Albert H. Fay. 23 pages. Report of the Director of the Bureau for the Fiscal Year Ended June 30, 1914. 101 pages. Technical Paper 76, Notes on the Sampling and Analysis of Coal, by Arno C. Fieldner. 61 pages, illustrations. Washington, Government Printing Office, 1914.

The Nation's Security. How About Our Army and Navy? Speech of Hon. Augustus P. Gardner, of Massachusetts, in the House of Representatives, October 16, 1914. 8 pages, 8vo. Washington, Government Printing Office, 1914.

Judicial Recall. An address delivered at St. Louis, Mo., on September 23, 1914, before the State Bar Association of Missouri, on "The Dilemma of the Judicial Recall," by Rome G. Brown, chairman of the American Bar Association Committee to Oppose Judicial Recall. 21 pages, 8vo. Washington, Government Printing Office, 1914.

Comparative Trials of Mineral Lubricating Oils with the Addition of "Oildag." A. SAYTZEFF. (*Zeitschr. Ver. Deutsch. Ing.,* lviii, 1174.)—"Oildag" is a preparation containing pure, finely-divided graphite mixed with lubricating oil. It is manufactured and sold by the International Acheson Graphite Company, of Niagara Falls. The oils used for these trials were sold under the trade names of "Dynamo Oil E" and "Etna Engine Oil." The method of Petroff was employed for the determination of the internal friction (u), while the oil-testing machine of Martens was used to determine the resistance to friction (u), and the frictional coefficient (f). Full details of the tests, with tables and diagrams, are given. The practical results are summarized thus: (1) The value for the internal friction (u) remains fairly constant for the oils, whether treated with 1.5 per cent. oildag or not. (2) The mixture of 1.5 per cent. oildag with the mineral oils produces an almost perfect lubricating medium, and reduces the friction by 30 per cent. The mechanical friction of the thick "Etna" engine oil was diminished 7 per cent. by the addition of 1.5 per cent. oildag. (4) In all cases an addition of 1 per cent. to 2 per cent. of oildag to the oils produces a noticeable economy in oil consumption.

CURRENT TOPICS

Plastic Deformation of Steel During Overstrain. H. M. Rowe and A. G. Levy. (*Amer. Inst. Mining. Engin. Bull.,* lxxxviii, 585.)—The authors have made a microscopic study of the deformation of 0.2, 0.4, 0.75, and 1.45 per cent. carbon steels during the processes of cylindrical and conical punching, tensile testing, and wire-drawing. There are four aspects of flow in the plastic deformation of steel by overstrain: (1) The relative movements of the grains as a whole; (2) the relative movements of the cementite and pearlite within the grains; (3) the relative movements of the ferrite and cementite in the pearlite; and (4) the crystal unit slipping giving rise to the slip-bands of Ewing and Rosenhain. Intergranular movements are best shown by the uplifting of the grains on the upper surface of the plate polished previous to punching. The displacements are greater in cylindrical than in conical punching, but are confined to a narrower ring in the former case. Study of intra-pearlitic deformation shows that elongation or compression parallel to the stratification results in drawing out the cementite lines into squads and rearranging them *en echelon.* Sometimes the cementite lamellæ curve greatly, but cementite islands resulting from divorce annealing are shattered.

French Electrochemical and Electrometallurgical Industries. (*For. Off. Ann.,* Ser. No. 5324.)—A large company hitherto engaged in the manufacture of paper and sodium at Rioupéroux, in the valley of the Romanche (Isère), from whose waters it derives its power, has given up these branches of industry, as the result of a lawsuit, and has taken up instead the manufacture of ferro-alloys and calcium carbide. The French syndicate controlling the manufacture of the latter product has recently made a substantial reduction in its price, with a view of combating competition.

The company working the Paul Girod patents for the manufacture of special steels and ferro-alloys at Ugines (Savoie) and elsewhere has lately acquired further works and water-power on the Bon Naut, near St. Gervais-les-Bains. In future the manufacture of ferro-alloys will be confined to the Ugines works of the company, while that of calcium carbide will be carried on at its works in Switzerland. Licenses have been granted for working the Paul Girod processes to the Bethlehem steel works, and the French company is at present engaged in mounting extensive plant in the Ansaldo-Armstrong works in Italy and the Putiloff works in Russia. The two Paul Girod companies—for ferro-alloys and electric steels, respectively—have lately reorganized their finances by means of a drastic reduction of capital.

Large hydro-electric works are about to be erected at Laroquebrou (Cantal) for the production of sodium nitrate in the electric furnace. The motive power will be furnished by means of a dam to be built across the Cère, causing a water-fall 488 feet high. The cost of this enterprise is estimated at £800,000. Another works for the manufacture of artificial nitrates is in contemplation at Bouvillard, near Aiguebelle (Savoie), with power derived from the Arc at La Chambre. The manufacture of electrodes is actively carried on in the works of the Electrode company situated at Venissieux, on the outskirts of Lyons, whose output exceeded 5000 tons in 1913. Up to the present time no nitrides have been produced by the Société Générale des Nitrures at its works at St. Jean de Maurienne. Arrangements are said to have been made with a Norwegian concern with works at Arendal (25,000 horse-power) for the production of nitrides on account of the French company for importation into France, this move being explained as necessitated by the lack of sufficient power in the St. Jean de Maurienne works. Another company is at present engaged in perfecting a rival process, the invention of Coutagne.

Electric Welding of Platinum Contacts. H. E. WEIGHTMAN. (*Elect. Rev. and West. Electn.*, lxiii, 686.)—Platinum contacts are now electrically welded on to springs, the principal advantage being the saving in the amount of platinum used per contact. The process is facilitated by having a thin coating of copper plate on the platinum and the current necessary for welding is thereby reduced. The welding machine is automatic, and takes a strip of platinum sheet 0.005 inch thick and 0.115 inch wide, or a coil of platinum wire, according to whether a flat or pointed contact is required. The strip or wire is fed to the clamping device, which cuts off the proper-sized piece, deposits it upon the spring, and holds it in position during welding. The welded contact is flattened or pointed by a die as it leaves the machine. Oscillograms of the current and the electromotive force during welding are given.

New White Metal Alloy. EDWARD SMITH. (*U. S. Patent 1,114,055.*)—This new alloy greatly resembles silver, and withstands atmospheric conditions to a great extent. It is suitable for the manufacture of goods which are to be silver plated. To make it, 8½ pounds of nickel are melted with a flux of silica, 20 pounds of copper are added gradually and mixed, and then 20 pounds more copper are added. Then 5 pounds of zinc are plunged beneath the molten metal, which is stirred rapidly till the whole is melted. Two and one-half pounds tin and one pound lead are added last to the liquid. Stir and heat up to 1700° F., then pour into ingot moulds.

Theory of the Coking Process. E. DONATH. (*Stahl und Eisen,* xxxiv, 60.)—A sample of coal from Rossitz, near Brunn, containing ash 4.64, water 9.66, nitrogen 1.32, hydrogen 4.86, carbon 82.88, total sulphur 3.35, sulphur in ash 0.32, combustible sulphur 3.03 per cent., when heated in an experimental coke-oven gave a molten product sufficiently fluid to flow from a small opening at the base of the oven. This product quickly solidified to a shining black mass, containing ash 10.47, water 0.50, nitrogen 0.14, hydrogen 2.99, carbon 76.86, total sulphur 3.63, sulphur in ash 2.18, combustible sulphur 1.45, oxygen 7.59 per cent. The whole of the organic constituents were volatilized when the product was heated in a covered crucible, leaving only the ash. This behavior resembles that of tallow, wax, and paraffin and some resins, and the author concludes that during the coking of a coal of this type a mixture of compounds, consisting of the degradation products of the resinous and fatty constituents of the original coal-forming materials and also the pitch-like polymerized products of distillation under pressure, is completely melted, and decomposes on further heating without leaving any carbon residue. The decomposition products react chemically with the degradation products of the cellulose and protein constituents of the coal-forming material, cementing them into a carbon-like compound or mixture of compounds. At higher temperatures the protein degradation products in the coal soften, and during the complete gasification of the coal, stable compounds are formed containing sulphur and nitrogen, and these compounds are present in the coke.

A Chemical Compound Obtained from Wool and Indigo. M. FORT and L. L. LLOYD. (*J. Soc. Dyers and Col.,* xxx. 297.)—Indigo dyed wool was extracted with boiling acetic acid and the extract diluted with water. A precipitate formed containing wool substance and indigo in fixed proportions. Similar results were obtained with other solvents and methods of isolation, and it is concluded that a definite wool-indigo lake is formed on the fibre when wool is dyed with indigo, which explains the superior fastness of indigo dyed on wool to indigo dyed on cotton.

Manufacture of Tungsten. A. JUST. (*British Patent 8956 of 1913.*)—A small percentage of another metal such as vanadium, molybdenum, chromium, or tantalum is added to the previously-prepared pure tungsten, and the mixture is gradually heated up to about 2000° C., according to the ordinary sintering process, or the mixture is melted at 3000° C. In both methods the maximum temperature must be maintained for some time to allow the tungsten to dissolve the added metal. The mixture is then suddenly cooled so that a crystalline, solid solution of one of the above metals in tungsten is obtained. This product is tempered in an electric furnace in a current of pure hydrogen or nitrogen. It is well suited for wire drawing.

Hardened Oils in Competition with Copra Oil. E. W. THOMPSON. (*Amer. Perfumer,* ix, 139.)—"Compound" lard in the United States is now made chiefly from hydrogenated cotton-seed oil. The total capacity of plant for hardening oils in Europe for 1914 is estimated at 1,375,000 barrels of 400 pounds each, and the United States output for 1913 at 500,000 barrels. The composition of margarine in Europe in 1913 is estimated at: Copra oil, 169,000; palm-kernel oil, 35,000; animal fats, 143,500; and fluid oils, 150,000 metric tons. Copra oil is being increasingly used for the purpose, and the estimated demand for 1914 is 250,000 tons, or two-thirds of the world's supply. Since 1906 the amount of copra oil produced has trebled. Small quantities of hydrogenated cotton-seed oil are now used in the manufacture of margarine in Europe.

New Powerful Search-lamp. ANON. (*Sci. Amer.,* cxi, No. 7, 111.)—A new powerful search-lamp is undergoing test at the New York Navy Yard, in which high efficiency is obtained by using a greatly concentrated arc light. Heretofore it has been found that, after a certain intensity has been reached, further increase of current results chiefly in spreading the incandescence over a larger area of the electrode. In the new search-lamp the area of the light source is even smaller than heretofore, because the electrodes are much smaller, and they are protected from rapid combustion by a cooling stream of alcohol vapor. The new electrodes are but 16 mm. in diameter, as compared with 38 millimetres for a current of 150 ampères in previous lamps. The alcohol vapor confines the illumination to the tip of the positive electrode, which hollows out into a crater filled with incandescent fumes, backed with white-hot carbon. The small spot of intense brilliancy approaches more closely to the theoretical point of light which is necessary to secure a perfectly parallel beam. The strength of the beam of the new lamp is about six times as great as that of the old. The alcohol vapor is generated by an electric resistor. To obtain a uniform bathing of the electrodes in the vapor, they are rotated.

Latent Heat of Vaporization of Carbon. C. HERING. (*Met. and Chem. Eng.,* xii, 526.)—The energy liberated when solid carbon combines with gaseous oxygen, $C + O = 26.1$ kilo-cals., and $C + O_2 = 94.3$ kilo-cals., is represented by the difference between the chemical energy of combustion and the physical energy required to render the carbon gaseous. Richards estimates the latter value at 45.7 kilo-cals. By reducing this figure from 45.7 to 42.1 (about 9 per cent.) the equations are $C + O = 26.1 + 42.1 = 68.2$ (which is identical with $CO + O = 68.2$), and $C + O_2 = 94.3 + 42.1 = 136.4$ or 68.2×2 kilo-cals. It would thus appear that carbon develops exactly as much energy in combining with the first atom of oxygen as it does with the second.

The "Half-watt" Lamp in Photography. M. LUCKIESH. (*Electr. World,* lxiv, No. 3, 129.)—The high-efficiency tungsten lamp is very valuable in photography. Much photographic work by artificial light is effected by the use of the mercury-vapor lamp, which produces powerful effects on the ordinary plate or printing paper by reason of the enormous intensity of three lines in the blue-violet region. Mr. Luckiesh's experiments show that the new gas-filled lamps will prove of considerable practical value in photography. They are much better than the ordinary tungsten lamp and as good as the direct-current open arc lamp. The half-watt lamp has considerably less actinic value than the mercury-vapor lamp, but this deficiency is largely compensated by the ease with which concentrated illumination can be obtained by the use of reflectors. A more interesting possibility resides in the use of the half-watt lamp in orthochromatic photography, although this lamp alone fails to produce a well-balanced light for orthochromatic work. However, by the use of suitable screens the light can be toned down to reproduce daylight. Perhaps the strongest point on the practical side of the matter is the ease with which the concentrated filament-types of the half-watt lamp can be made to produce a flood of light on the objects to be photographed, so that by very simple apparatus adequate light can be obtained even for instantaneous work in the studio.

Polychrome Screen Plates for Color Photography. A. and L. LUMIÈRE. (*French Patent 467,128.*)—One of the difficulties in preparing polychrome screen plates is due to the screen presenting a certain amount of color, which affects the general tone of the finished photograph. It has not been found possible to correct this by staining the gelatin emulsion, but satisfactory results have been obtained by the use of a layer of varnish of a color complementary to that of the fault in the screen. The varnish may be introduced between the screen and the emulsion or it may be applied to the glass.

Portland Cement in Peru. (*Sci. Amer.,* cxi, No. 9, 143.)—Heretofore Peru has obtained Portland cement entirely from abroad, large quantities being purchased in the United States, England, and Belgium; but recently a company has been formed in Lima to undertake the manufacture of cement. Suitable material is said to be plentiful.

Mineral Railways in Spain. (*Sci. Amer.,* cxi, No. 9, 143.)—A number of short railways, ranging from 12 to 74 miles in length, have been projected in Spain to facilitate the shipment of ores; and several of them are already under construction. These lines are located in the region between Madrid and Cordoba, and will greatly promote the development of the rich mineral district in that part of the country.

Space Lattice of Diamond. M. BORN. (*Ann. d. Physik,* xliv, No. 4, 605.)—This is a mathematical paper which may be thus summarized: (1) According to the Braggs, the diamond space lattice has the property that each carbon atom has four neighbors. Under the assumption that only these four neighbors exert molecular forces on the atom, diamond is shown to have only two molecular elasticity constants. (2) The vibrations proper to the lattice are rigorously calculated. It is shown that, as for the simplest regular lattice, the frequency is determined by a cubic. (3) The limiting case of long waves furnishes the relation between the three measurable and the two molecular elasticity constants. Among the measurable constants there is an equation of the second degree. (4) The formula for the specific heat is developed in a series in the reciprocal powers of the temperatures, according to the method of Thirring, and the first seventeen coefficients of the series are calculated. (5) The tabulation and plotting of the specific heat for various values of the elasticity constants are thus possible. (6) For an isolated carbon atom the appropriate frequency corresponds to a rest-ray wave-length of 11μ, in accordance with Einstein's statement. The frequency used by Debye may thus be calculated theoretically.

Steel Production in the United States. ANON. (*Eng. and Min. J.,* August 1, 1914.)—The Statistical Bureau of the American Iron and Steel Association states that the production of steel in the United States in 1913 was the largest ever reported. A further decrease in the make of Bessemer or converter steel, and a large increase in open-hearth steel, chiefly basic metal, are noteworthy.

The production in 1912 and 1913, in tons, was:

	1912	1913
Bessemer	10,327,901	9,545,706
Open-hearth	20,780,723	21,599,931
Crucible	121,517	121,226
Electric	18,309	30,180
Miscellaneous	2,853	3,831
Total	21,251,303	31,300,874

Included in the open-hearth steel are 1,255,305, tons made by the acid process and 2,210,718 tons produced by the duplex process, made from metal partly treated in Bessemer converters and finally purified in open-hearth furnaces. This is an increase of 772,064 tons over the previous year.

In 1913 the production of steel treated with ferrovanadium, ferrotitanium, nickel, and other alloys was 714,357 tons, a decrease of 78,144 tons from 1912. The total included 74,924 tons Bessemer steel, 213,404 acid open-hearth, 386,486 basic open-hearth, 28,279 crucible, and 11,264 tons electric and miscellaneous steel.

At the close of 1913 there were 30 plants equipped to make steel by the standard Bessemer process and 80 by the Tropenas or other modifications of that process. There were 119 basic and 93 acid open-hearth plants, 29 of them being equipped to make both acid and open-hearth steel. There were 110 crucible steel plants and 19 electric plants.

Mirror Astrolabe. H. CHRÉTIEN. (*Comptes Rendus,* clviii, 1144.)—A modification of the Claude and Driencourt prism astrolabe is proposed, substituting for the prism a mercury bath and two plane reflectors fixed at 60 degrees to each other, the angle of intersection being horizontal and normal to the plane containing the axial reflected ray. If the telescopic objective is then arranged with its axis inclining 30 degrees to the vertical, it will receive light from a star about 60 degrees altitude along two paths: the first after reflection from the mercury surface and transmission through the glass of one mirror; the second after reflection from each mirror surface. Advantages are expected on account of the homocentricity of the two luminous periods, the augmented definition, and the possibility of constructing large instruments at moderate prices.

The Velocity of Flame in Mixtures of Methane and Air. A. PARKER and A. V. RHEAD. (*Chem. Soc. Trans.,* cv, 2150.)—In connection with the study of fire-damp explosions in mines, the authors determined the velocity of flame propagation in mixtures of pure methane and air in straight horizontal tubes of glass, lead, copper, and iron, 6.5 metres long and about 2.5 cm. in diameter. The tubes were closed at one end, and the gas was ignited at the open end by a spark. The progress of the flame was recorded electrically by the fusing of thin strips of Wood's alloy, arranged 1 metre apart in the tubes. The flame travelled at a constant velocity for about 4 metres, then oscillated with increased velocity of propagation, and finally attained a constant velocity towards the end of the tube. The initial velocity varied with the strength of the mixture and with the material of the tube, being least with tubes having a high conductivity for heat. The maximum initial velocity was 70 cm. per second with a mixture containing 10 per cent. methane. The limits of inflammability occurred with methane 4.5 per cent. and 13.1 per cent. respectively.

Specially Hard Lathe Tools. ANON. (*Brass World,* x, No. 11, 441.)—Lathe tools are now made which surpass in hardness those made of the finest special steels, and which outlast them many times in cutting metals. They are composed of an alloy of cobalt, chromium, and tungsten invented by Elwood Haynes, of Kokomo, Ind., president of the Haynes Automobile Company. These alloys are also used for cutlery and take an edge equal to good steel and yet are very non-corrosive.

Three-metal Bronzes. A. M. BLOW. (*Met. and Chem. Eng.*, xii, 461.)—A description of the ternary systems: Copper-Tin with lead, zinc, phosphorus, manganese, and aluminum. *Lead* imparts plasticity to bronze, and diminishes hardness and temperature changes ("imparts a lower mutual freezing-point"). Microscopic examination shows that the lead is distributed throughout the mass. Segregation, to which bronzes rich in lead are liable, is prevented by the addition of 1 per cent. nickel, sulphur added as galena, phosphorus, or arsenic. A small addition of *zinc* does not materially alter the structure of bronzes, while ductility and tensile strength are slightly increased. Bronzes containing zinc are more easily forged and cold-rolled and are less readily corroded by sea-water. *Phosphorus* may exist entirely as solid solution (up to 1 per cent.) or as Cu_3P; it greatly increases the hardness and resistance to wear, while impairing the tensile strength, elasticity, and elongation. The maximum in commercial bronzes is about 0.8 per cent. P, with about 8 per cent. Sn. The valuable properties of *manganese* bronze are its strength and non-corrodibility; commercial products often contain more aluminum than manganese. True *aluminum* bronze seldom contains more than 11 per cent. Al; it is useful in casting, though it shrinks considerably. The addition of tin increases its ductility.

Coal-tar Dyes. ANON. (*Ch. of Comm. J.*, Oct., 1914.)—The value of the imports of coal-tar dyes to the United Kingdom from Germany in 1913 was: Alizarin and anthracene dyes, £271,119; aniline and naphthalene dyes, £1,382,478; synthetic indigo, £76,681; other kinds, £543; total, £1,730,821. Not only has the demand of the United Kingdom to be met, but also the important requirements of India, Japan, China, Turkey, Egypt, etc. India imported from Germany in 1911–12 dyes to the value of £516,939. Japan, in 1913, imported dyes to the value of £699,568. China imported from Germany in 1911 artificial indigo to the value of £575,000.

Action of Radium Emanation on Mixtures of Hydrogen and Oxygen. O. SCHEUER. (*Comptes Rendus,* clix, 423.)—In mixtures of hydrogen and oxygen produced by electrolysis, rapid combination occurs under the influence of radium emanation, whether the latter is mixed with the gases or enclosed in a bulb. The ratio of the number of molecules of gas combined to the number of pairs of ions formed per Curie-second is independent of the pressure of the gas, and varies from 5.4 : 1 to 5.6 : 1 when the emanation is mixed with the gas. The products are water and smaller quantities of hydrogen peroxide; the greater part of the former is probably produced by the decomposition of hydrogen peroxide. No ozone is produced, and only minute quantities are formed by the action of radium emanation on pure oxygen.

Rutile Deposits Yield Titanium.—Rutile, from which is derived the metal titanium, is a reddish, brownish, or nearly black mineral composed of titanium dioxide, and, though it is widely spread through the rocks, it is rarely found in large quantities. Titanium exists in larger quantity in the earth's crust than copper, lead, zinc, or any of the common metals except iron, but it is called one of the rare metals because of the lack of concentrated deposits and because the metal is so difficult to separate that it has been seen by few people.

The value of rutile arises from the use of titanium as a scavenger in molten steel and cast iron, and from the use of titanium salts in dyeing textiles and in tanning leather. The largest known deposits of rutile are at Roseland, Nelson County, Va. A few other much smaller deposits have been found in the eastern part of the United States, and still other deposits, also much smaller than those in Virginia, have been found in foreign countries. Dr. Thomas L. Watson, State geologist of Virginia, has described all the known deposits, laying stress on those in the United States, in Bulletin 580–O of the United States Geological Survey. The bulletin may be obtained free of charge by applying to the Director, United States Geological Survey, Washington, D. C.

A New Mineral Found in Tasmania. ANON. (*Sci. Amer.*, cxi, No. 11, 207.)—Many rare minerals exist in Tasmania and a new addition has been made to the list by the discovery of molybdenite, which is used in the manufacture of molybdenum steel, to which it imparts special hardness and toughness. As the present price of the mineral is about $2500 per ton, this discovery should prove of considerable value.

Uses of Tungsten.—Tungsten is used principally as an alloy of high-speed steel,—that is, steel used in making tools used in metal-turning lathes running at high speed,—to which it imparts the property of holding temper at higher temperature than carbon steels will, according to the United States Geological Survey. The now well-known ductile tungsten is used for incandescent lamps, which are fast displacing carbon lamps. Recently greatly improved lamps, in which the wire is wound in helices and in which the globes are filled with nitrogen, have produced a close approach to white light. These lamps are furnished in candlepowers up to 2000. Ductile tungsten is practically insoluble in all the common acids; its melting-point is higher than that of any other metal, its tensile strength exceeds that of iron and nickel, it is paramagnetic, it can be drawn to smaller sizes than any other metal (0.0002 inch in diameter), and its specific gravity is 70 per cent. higher than that of lead.

PRESS OF
J. B. LIPPINCOTT COMPANY
PHILADELPHIA

JOURNAL

OF

THE FRANKLIN INSTITUTE

DEVOTED TO SCIENCE AND THE MECHANIC ARTS

VOL. CLXXIX   FEBRUARY, 1915   No. 2

SOUND STEEL FOR RAILS AND STRUCTURAL PURPOSES.*

BY

SIR ROBERT A. HADFIELD, F.R.S.,

Member of the Institute.

WITH reference to the recent interesting paper by Dr. Allerton S. Cushman on "Research in Metallurgy of Iron," which appeared in the July JOURNAL, and its reference to sound steel, the writer desires to put the following statements before The Franklin Institute, as a contribution on this important question of producing steel which can be safely used for railroad track work and structural requirements generally.

The various papers by the writer on this subject are shown in Table III at the end of the paper. These are given as reference for those who may wish to further investigate this matter.

As rightly pointed out in Dr. Cushman's valuable paper, the question of sound steel is of the utmost importance, covering, as this does, the production of sound rails. The rail problem in America is a serious one and concerns the safety of the travelling public, yet rails continue to be produced from ingots made in practically the same manner as used for years back; in fact, ingot-making practice is pretty much the same to-day as it was ten years ago. This is the more to be regretted when simple, cheap,

---

* Communicated by the Author.

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

Copyright, 1915, by THE FRANKLIN INSTITUTE.

and efficacious methods are in existence by which the trouble and dangers now met with can be overcome. In other words, there is not the slightest necessity that unsound material should be produced for rail or other purposes; in fact, strange as it may seem, there is also no reason why a single unsound ingot need be produced. This is shown by the following research work which the writer has carried out during the last few years.

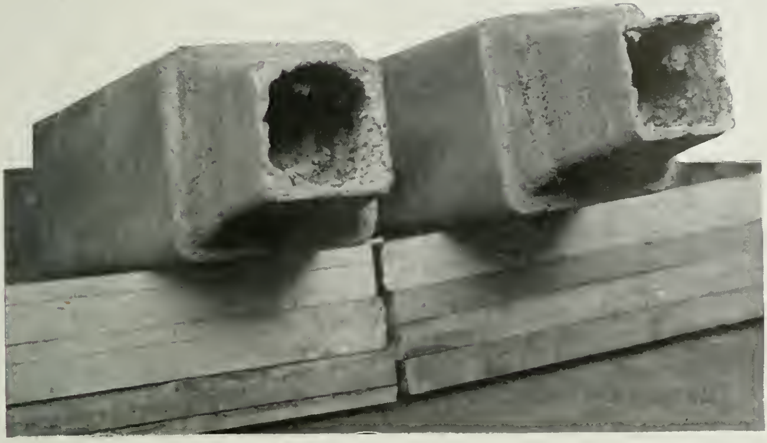
Photograph No. 2074 (Plate I) represents two 18-inch ingots made by the writer's system, weighing about 2¾ tons each. These ingots were cast with the small end up, as in ordinary practice. This photograph is interesting, as it gives an excellent view of the cavity produced by the sound steel in these ingots as it settles down into the body of the ingot proper; that is, below the feeding head. As previously mentioned, in these ingots it is not necessary, in order to determine whether they are sound or not, that machining or other observation by mechanical methods should be carried out, and at least 88 per cent. to 90 per cent. of sound usable and salable material is obtained. This, too, can be accomplished just as readily and easily with 10,000 or 100,000 as with one ingot.

If the reader will examine photograph No. 2065 (Plate II), which shows an ingot made in the present and ordinary manner, he will see that not even the most experienced expert could say whether the interior of the ingot was sound or unsound, whereas the ingot in photograph No. 2074 (Plate I) shows the steel to have settled or sunk down. When steel so sinks it is a definite proof that the material is sound and free from blowholes. In other words, the presence of this cavity is conclusive evidence of the soundness of the steel. If the steel were not sound there would be no cavity, so that this particular quality of soundness of the steel is made self-apparent.

The following results further illustrate this important advance in the production of sound steel:

To show how considerable is the cavity which forms in piping steel, nine 15-inch ingots were taken (weighing about 3600 pounds each) as they came through, each of which had the sand head and the writer's improved method of feeding carried out on them. After the ingots had cooled down, the hollows or cavities in the sand heads were filled with water, then the water poured out and carefully measured. Table I shows the results obtained.

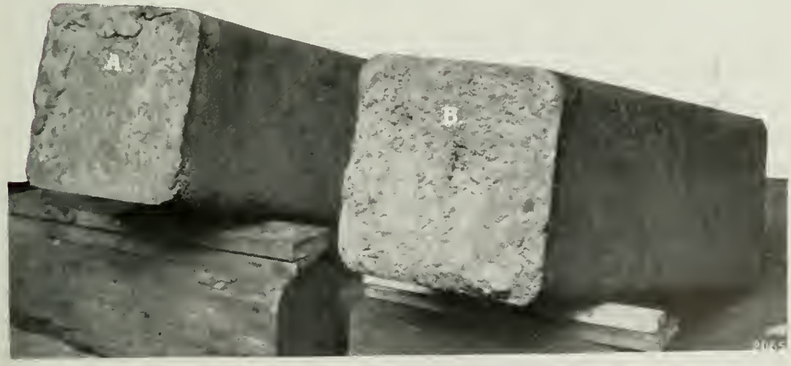
PLATE I.



18-INCH INGOTS, WEIGHING ABOUT $2\frac{3}{4}$ TONS. THESE INGOTS WERE MADE BY THE HADFIELD PATENTED METHOD FOR PRODUCING SOUND INGOTS.

Photograph No. 2074.

PLATE II.



18-INCH INGOTS, WEIGHING ABOUT $2\frac{1}{4}$ TONS. INGOT A, UNSOUND INGOT. INGOT B, PIPED INGOT.

Photograph No. 2065.

TABLE I.

Ingot number	Cubic inches	Pounds of steel	Percentage of weight of ingot
1	457	128	3.57
2	549	154	4.30
3	457	138	3.57
4	457	128	3.57
5	472	132	3.68
6	488	137	3.82
7	518	145	4.05
8	579	162	4.52
9	488	137	3.82
Average	496	139	3.88
Maximum	579	162	4.52
Minimum	457	128	3.57

Weight of Ingot, 3600 pounds.

The average weight for the nine 15-inch ingots showed that 139 pounds, with a minimum of 128 pounds and a maximum of 162 pounds, passed from the head portion into the ingot itself. This percentage is represented by an average figure of 3.88 per cent. In other words, about 4 per cent., or 140 pounds, of the total weight of the ingot or ingots cast passed from the upper or feeding head into the body of the ingot.

There could not be a more striking illustration of the quality of the ingots produced and of the value of this system. Even in the case of the minimum percentage weight of steel which passed from the head of the ingot itself, there is a weight of no less than 128 pounds of steel short in the head, and therefore present in the ingot itself, all adding to the soundness and proper feeding of the piping which would otherwise occur.

To show still more clearly the important information obtained from these experiments, let it be assumed that the cubic capacity of each of the 15-inch ingots in question was approximately 12,500 cubic inches. Therefore, but for this feeding, there would be a general want of solidity, chiefly at the upper portion of the ingot, to the extent of, say, 500 cubic inches—say, 4 per cent.—of the whole capacity. It is surely readily apparent why an ingot which is not fed must perforce be deficient in homogeneity.

It is not claimed that ingots made in the ordinary manner are deficient to the full extent of, say, 4 per cent., even when the steel is sound, which, unfortunately, is usually not the case. There is a certain amount of feeding effect from the steel in the upper portion of the ingot, but this is not done efficiently, as the steel quickly freezes on the outside of the mould and on the surface of the liquid steel exposed to the air. Moreover, there is always an uncertainty as to how good or how bad is the resulting material. If the steel is piping very much, the trouble will be worse than when it is piping less. In any case, as the steel solidifies in an ingot of this size, the natural law of contraction demands that about 500 cubic inches have to be dealt with; that is, on an ingot of the weight and size mentioned. The writer cannot see how this can be efficiently and cheaply met except by some such method as described in this paper.

While the results necessarily vary slightly, because the sizes of the head portion nearest the top of the mould formed in sand are not always uniform in length, as the steel shrinks down slightly more on the outside in some cases than others, on the whole the maximum and minimum figures of 4½ and 3½ per cent. of the total weight of the ingot having passed from the head into the ingot itself show very uniform working; if the heads were absolutely the same depth in each case, there would be practically no difference.

Without wishing to exaggerate, it is easy to picture to oneself what would be the character of each of these ingots, if not made and treated under the method now described. The piping would have probably run down the ingot itself, requiring a discard of probably 25 to 33 per cent.

Although water cannot be poured into the cavity of a red-hot ingot, yet the cavity can be determined in each ingot by a cursory examination while at a red or yellow heat, involving only a few seconds of time. It will, therefore, be seen that every ingot can be readily checked by such cursory examination.

While in ingots made in the ordinary way as above mentioned a certain amount of the fluid steel passes from the upper portion to the lower, still in so doing it is robbing the quality of the upper portion of the ingot itself, which has no fluid metal above it to feed or take the place and supply the deficiency thus created. It will readily be understood, therefore, why the upper portion of ingots is so seriously affected as regards their soundness, also why segregation occurs. This is shown in a remarkably clear manner by Fig. B in Plate IV, showing an ingot made in the ordinary manner in America and afterwards cut up by the Standards Bureau. The occurrence of these defects varies according to the type of steel, whether rising, semi-rising, or settling nature.

Again referring to this question of the cavities, if, as proved by these experiments, in the ingots made under the writer's system the metal in the sand head portion in descending has without doubt felled or prevented the formation of what would otherwise have been unsoundness, piping, loose structure, or segregated material. In unfed ingots made in the ordinary way there must be steel of loose structure; if not, then in many cases absolute unsoundness and segregation.

Moreover—and this is a most important point—the steel in the "fed" ingots, being maintained fluid in the head portion, continues to exert its ferrostatic pressure, whereas with ingots made in the ordinary way the ferrostatic pressure on the centre portion of the ingot is so slight that it produces very little beneficial effect. Further, without the feeding head above the ingot proper, the outside of the ingot in the ordinary ingot mould becomes rapidly chilled and frozen, so that it cannot contribute its proper share to the feeding of the remaining portion of the ingot. It is not, therefore, to be wondered at that rails rolled from the A and B portions of an ingot made in the ordinary way are liable to unsoundness or piping, or both, and are also often full of impure segregated material.

There would probably be more dangerous ingots but for the fact that the steel maker tries to avoid this type of steel, and aims to make steel which when poured into the ingot will not pipe. Nevertheless, he is still fighting against a natural law. If piping steel is checked or avoided, he runs the risk of producing unsound steel, especially in the upper portion of the ingot, more or less permeated with blowholes. Thus, owing to lack of feeding from the upper portion, the centre, or that portion on the axis line of the ingot, must be of inferior nature, as the piping characteristics persist for quite a long way down the ingot. This, as before mentioned, is for the reason that, owing to want of ferrostatic pressure, the ingot lacks feeding from above, which, in the system of casting ingots now described, is maintained to a very late stage; that is, until or close upon actual solidification takes place. There is always fluid steel in the upper portion of the ingot to feed the piping and shrinkage, both of which must occur, as they follow a natural law. This, too, is the reason why there is so little segregation in ingots made under the writer's system, and also explains why the ferrostatic pressure is kept up to a very late stage. In fact, check or hinder ferrostatic pressure, and segregation, with its bad effects, at once commences. In the case of "fed" ingots, the smaller amount of segregation which occurs takes place outside the ingot proper; that is, in the head.

With steel of piping nature poured into the ingot moulds and not fed, it need cause no astonishment to find that rails, even from C and D portions of the ingots, may be of material with loose structure, consequently weak, if not actually unsound, thus giving inferior or bad results in service. With piping steel not properly fed, there is extreme danger of this pipe extending a long way down the ingot; in fact, in some cases it has been found to go as much as two-thirds the length of the ingot. Ingots have also been found in which the piping has apparently stopped, only to be resumed below the sounder steel.

The experiment carried out by the writer some years ago, by the pouring of copper into the upper portion of an ingot 15 or 20 minutes after casting, showed how serious is this want of ferrostatic pressure in the material situated on or near the centre or axis line of the ingot in ingots which have not been properly fed. The copper finds its way down to the bottom of the ingot, although added 15 minutes after casting. This is illustrated by Plate III. In any case, if there is no definite pipe at the bottom portion of such ingot, there is still material of loose or open structure, which means weak steel. Although this may not be apparent by fracture to the naked eye, nevertheless it exists, and can generally be detected by an examination of the microstructure. In other words, notwithstanding that the product to be used may come from the lower half of the ingot, yet in unfed ingots it will be weak and not able to stand severe stresses. This is probably the real explanation of the serious breakages which sometimes occur in even C and D rails. Imperfect material is present; only time and sufficient working stresses are wanted to develop its existence and weakness.

It is true that some portions of the cavities in ingots have been measured, but probably not in the manner described by the writer.

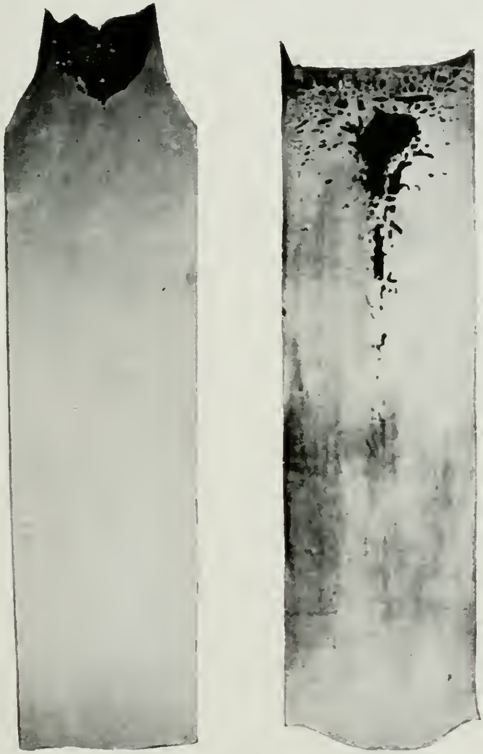
Although in the examination of the top of an ingot cast in the ordinary manner and from steel which "settles" there is external evidence of some piping, this is irregular and varies considerably. Therefore, in the "best" ordinary ingot proper evidence is slight as to how much or how little the steel has piped. Dr. Dudley has pointed out, in his interesting paper to the Institute on "Piping and Segregation of Ingots of Steel and Ductility-tests for Open-hearth Steel Rails," read in February, 1913, that in such ingots the piping is divided into two kinds: the upper, or what may be termed the visible pipe, and the lower, or hidden pipe, the extent and character of which can be determined only by cutting open the ingot. In the ingots cast under the writer's system, *all the cavity or pipe is open* and can readily be inspected from the top; its extent can be determined whether in the hot or

PLATE III.

cold condition. It is, therefore, not necessary to cut open the ingot. In other words, such cavity produced by the piping is "the outward and visible sign of an inward and spiritual grace"—"spiritual grace" in this case meaning "soundness."

PLATE IV.

FIG. A FIG. B



INGOT MADE BY THE HADFIELD SYSTEM. PERFECTLY SOUND, FREE FROM BLOWHOLES PIPING, AND SEGREGATION.

INGOT MADE IN ORDINARY MANNER. UNSOUND, WITH BLOWHOLES, PIPING, AND SEGREGATION.

Photograph No. 2221

Dr. G. K. Burgess, of the Bureau of Standards, Washington, is at present working with the writer on a joint research relating to this subject, and, though the full details of the work done cannot at the present time be given, it may be stated that ingots made under the writer's system were carefully cut up by the Bureau and compared with similar ingots produced at rail mills and made in the ordinary manner. The comparisons are shown by the enclosed photograph No. 2221 (Plate IV), in which Fig. A represents the ingot made under the writer's system, as described in the various papers, and Fig. B represents an average ingot made by one of the rail makers. It will be seen there is a remarkable difference in favor of ingots made under the writer's system. It is apparent that thoroughly satisfactory rails cannot be produced from ingots of the B type, representing ordinary ingots produced by the rail maker. In the writer's ingot, Fig. A, there are no blowholes and no segregation below the head portion. The ordinary ingot, Fig. B, is very unsound, badly piped, and is segregated through nearly half its total length.

While the average ingot used for rail manufacture is known to be imperfect, it is difficult to realize such ingots are so decidedly inferior as shown by Fig. B, but such is the case. This, it must be remembered, represents the results of an independent examination by no less an authority than the Bureau of Standards. The full report of this research will be shortly issued by the authors, namely, Dr. G. K. Burgess and the writer. It may be mentioned that this entirely confirms the great advantages to be obtained in ingots made by the system referred to in this paper. Moreover, the same authority states that rails rolled from ingots made under the writer's system show that the metal is quite sound, clear up to the front end of the first rail rolled (that is, immediately under the feeding head), whereas from the B ingot made in the ordinary manner, of which hundreds of thousands are turned out annually, at least two or three of the rails obtained are unsound and piped. It is doubtful whether there would be remaining even 40 per cent. of perfectly sound material, as against about 88 to 90 per cent. in ingots made under the writer's system.

A further exceedingly important advantage possessed by the writer's system is that it is possible to know definitely that *every ingot* made is good or bad *before it goes to the rail mill.* This is entirely a new feature, for, as ingots for rails are now made, they all look alike. An expert, if challenged to indicate by an outward examination of the ingots what would be the quality of the rails from the ingots as now made—for example, those shown in photograph No. 2065 (Plate II)—would be completely at a loss to express any opinion; it is not possible to see "into" (that is, inside) the ingot. On the other hand, with ingots made under the writer's system the soundness of every one can be determined by superficial examination, either when hot or cold, requiring only a few seconds. In other words, before the ingot goes to the rail mill it can be known whether the steel in the ingot itself is sound or not. If the hollow cavity is present, the material below in the ingot proper will be perfectly sound and free from honeycombs, blowholes, segregation, or piping. This cannot be determined in ordinary ingots; that is, it is impossible to ascertain by a superficial examination whether they are sound or unsound, or to determine the ñature of the unsoundness or piping present in them. The only way to make such determination would be to have each ingot sliced up by machining, and thus spoiled for actual work, before it could be decided whether the rail or other article produced from the ingot would be sound.

It is, therefore, difficult to understand why there is so much apathy in America with regard to this important matter, especially when the definite statement is made that it is possible to *check every ingot* and to know whether it is right or wrong, and whether safe for being used in the production of rails. As this is the case, it will be seen that the sound rail problem has been practically solved. Certainly no more accidents need occur owing to rails having imperfections due to unsoundness, blowholes, or segregation. It will be understood how important this is, for it means that breakages from these causes would entirely cease.

It is true that even a sound rail will sometimes break, but such cases are few. Moreover, some of the so-called mysterious breakages have really occurred in parts of rails which, while they have appeared to be sound, upon proper examination have been found to be microscopically unsound. In ingots made under the system now referred to, the material is free from this unsoundness. Segregation is entirely avoided; therefore, the whole of the material used is free from those internal defects produced by the piping and segregation found in ingots made in the ordinary way.

It will be seen, on looking at Fig. B in photograph No. 2221 (Plate IV), representing the average ingot now used, that it is not common sense to expect a rail produced from such an ingot to be sound. In rolling, the defects noticed may be closed up to some extent, but the final product must be of inferior strength. Compare this unsound ingot, Fig. B, with the sound ingot, Fig. A, when the above will be at once apparent.

To prove that unsound steel will not give the best test, even after being rolled and forged, a short time ago the following tests were made by the writer. The results now given are published for the first time. It will be seen that very important conclusions are arrived at by means of these experiments. The tests quoted were obtained under the following conditions.

The object aimed at was to see whether forged bars, rolled rails, or other worked forms, obtained from unsound ingots, give as good results as from sound ingots. It has been claimed that steel which is unsound in the ingot will, after being forged, show equal mechanical strength to that from sound ingots. The writer has long believed that this prevalent idea was probably not correct, and the results of the following tests show that there is considerable difference, as might be expected, as compared with unsound steel.

The experiments were carried out in the following manner: Three ingots of the same composition were selected, namely—

C	Si	Mn
0.87 per cent.	0.17 per cent.	0.78 per cent.

Ingot *A* (No. 3123C–1) To this aluminum was added. The ingot was provided with the feeding head described in this paper and was sound.

Ingot *B* (No. 3123C–2) To this aluminum was added. While the steel in this ingot was sound, it was not provided with the feeding head and was, therefore, piped.

Ingot *C* (No. 3123C–3) To this no aluminum was added. The ingot was unsound.

A portion of each of the ingots was forged into bars 1¼ inches square, and the usual mechanical tests were taken as shown in Table II.

In each case the mechanical tests from the unsound ingot were found to be considerably inferior. For example, test bar No. 7791F from the sound steel showed an elongation of 8 to 9 per cent., whereas the same steel made from the unsound ingot, and notwithstanding that it was forged, thus apparently closing up the blowholes, showed only 3½ per cent. elongation. The shock tests also confirm the superiority of the sound steel. It is, therefore, quite clear that rails, bars, or other products from sound

TABLE II.

MECHANICAL TESTS ON

(*A*) Sound ingots made under the Hadfield system.
(*B*) Piped ingots of similar type and nature to those at present made in rail mills.
(*C*) Unsound ingots; that is, blowholes, to which no aluminum was added.

The tests were carried out on forged bars 1¼ inches square.

Test No.	Ingot No.	Analysis			Type of ingot	Top or bottom	Tensile tests				Shock tests from specimen taken								Ball tests	
		C	Si	Mn			Yield point	Maximum stress	Elongation	Reduction in area	(*A*) Longitudinally				(*B*) Transversely					
											Fremont nick		"No" nick		Fremont nick		"No" nick		Longitudinally	Transversely
											Kgm.	Bending angle	Kgm.	Bending angle	Kgm.	Bending angle	Kgm.	Bending angle		
									p. ct.	*p. ct.*										
7791F	*A* (3123C–1)	.87	.17	.78	Sound. . .	Top. . . .	33	64	8½	14	1.2	2½	10	12	0.9	1	2	2	280	272
7792F	*B* (3123C–2)	.87	.17	.78	Piped . . .	Top. . . .	32	60	9	10	0.4	1½	11	18	1.2	1	3	2	276	274
7793F	*C* (3123C–3)	.86	.12	.79	Unsound.	Top. . . .	38	62	3½	3½	0.4	1	11	16	0.9	1½	3	1	280	283
7794F	*A* (3123C–1)	.87	.17	.78	Sound. . .	Bottom	35	65	10½	14	1.5	2	11	17	1.0	1½	10	13	274	269
7795F	*B* (3123C–2)	.87	.17	.78	Piped . . .	Bottom	37	65	9½	13½	1.5	2	13	10	1.5	1	10	12	274	277
7796F	*C* (3123C–3)	.86	.12	.79	Unsound.	Bottom	34	56	2½	3½	0.4	2	4	2	0.6	½	5	5	283	283

The material from *B* ingots being sound (that is, of the settling type), naturally shows good mechanical tests, but it is quite as dangerous as that from type *C*, because the pipe runs very far down the ingot. Very serious and dangerous defects often, therefore, exist, as the shrinkage or cooling of the steel is not properly fed.

Ingots of type *A* made under the Hadfield system show the best results in mechanical tests. Moreover, every portion of the ingot is of exactly the same character; there is no unsoundness, nor is there any piping. Ingots of the unsound blowhole type are not only bad in their unsoundness, but the rails produced from them are mechanically weak, as shown by the tensile tests.

steel are much safer and better in every way than when produced from ingots which were originally unsound.

While it is true that in unsound steel of very mild character the process of forging or rolling closes up the blowholes, and probably, if the heating temperature for rolling or forging is hot enough, the blowholes are welded together, but even then it is doubtful whether such material can ever afterwards possess exactly the same tenacity and ductility as the same steel worked up from a sound ingot. In the case, however, of rail steel in which the carbon percentage is high, the same amount of welding does not take place; in fact, it is doubtful whether the blowholes are more than merely pressed together; consequently the work cannot be so strong as regards tenacity or ductility.

As an addition to the present paper, and showing the efficiency of this method of making sound ingots, with its consequent advantages of the three important factors—(*a*) sounder material, free from piping and segregation; (*b*) better mechanical tests, including tensile and shock tests, (*c*) cheaper production—the writer also adds the results of further investigations completed only a few weeks ago. It is hoped they will prove to be of considerable scientific and practical value, entirely confirming, as they do, the conclusion arrived at with regard to the advantages of this system of making sound steel for ingots to be used in producing rails and other articles.

As large quantities of high explosive steel shell are used by various governments, it is most necessary to obtain steel of the highest quality and yet at not too high cost. In other words, there is required steel of superior quality to that ordinarily used for rails, ship and boiler plates, angles, bars, etc. The system of manufacturing ingots of sound steel described in the present paper exactly meets these special requirements. Moreover, it can be used for making the comparatively lower quality steel referred to; that is, lower quality of material as now made, owing to unsoundness, piping, and presence of segregation.

Several important governments, after making exhaustive tests, have been so satisfied with the Hadfield system of making sound ingots that, both for their land and sea services, they have now authorized explosive shell being made from ingots (afterwards forged into necessary billets) produced in the manner described in this paper.

As will be understood, an explosive shell, whether of small or large calibre, must be absolutely safe; that is, it must be (*a*) sound (that is, free from blowholes); (*b*) free from pipes; (*c*) free from segregation. Any flaw in the shell leading to its premature bursting would be most disastrous. In order to be absolutely certain of obtaining this combination of desirable qualities, it has, in the past, for ingots made in the ordinary manner, been insisted upon by the user concerned that something like 40 per cent. to 50 per cent. of the ingot—in fact, sometimes more than this—must be discarded or wasted; that is to say, only about 60 per cent of the total weight of the ingot was permitted to be used. Ingots made by the writer's method, however, are now allowed after discarding only 15 per cent. It would also be quite possible under the system to give perfectly safe shell with only 10 per cent. to 12 per cent. discard, and to ensure the qualities under the headings (*a*), (*b*), and (*c*) just referred to. This means a reduction in discard from 40 per cent. to 15 per cent. This decision has been arrived at after carefully cutting up and examining over one hundred ingots made by the Hadfield system; that is, not made specially, but produced in the ordinary course of working. Each of these ingots, on being cut up, was found to be perfectly sound,

TABLE III.

BIBLIOGRAPHY.

Papers by the Author.

Title	Name of institute where research was read, or press reference	Year of publication
"Experiences sur la Segregation dans les Lingots d'Acier"	*Revue de Metallurgie*	1910
"The Production of Sound Steel"	*Iron Age*	1912
"On a New Method of Revealing Segregation in Steel Ingots"	Iron and Steel Institute	1912
"Method of Producing Sound Ingots"	Iron and Steel Institute	1912
"Plant for Hadfield Method of Producing Sound Steel Ingots"	American Institute of Mining Engineers	1913
"Methode pour Produire des Lingots d'Acier sains et Deceler la Segregation dans les Lingots d'Acier"	*Revue de Metallurgie*	1913
"Nouvelle Methode pour Deceler la Segregation dans les Lingots d'Acier"	*Revue de Metallurgie*	1913
"Sound Ingots"	American Institute of Mining Engineers	1914

free from piping and segregation, and thus thoroughly suitable for the difficult class of projectile work mentioned.

In view of the peculiar nature of the purpose to which the steel now referred to has to be put (that is, for explosive shell), it is satisfactory to find that the discard hitherto necessary can be so greatly reduced, namely, to from only 10 per cent. to 15 per cent. of the total weight of the ingot, and yet at the same time the highest quality of material produced.

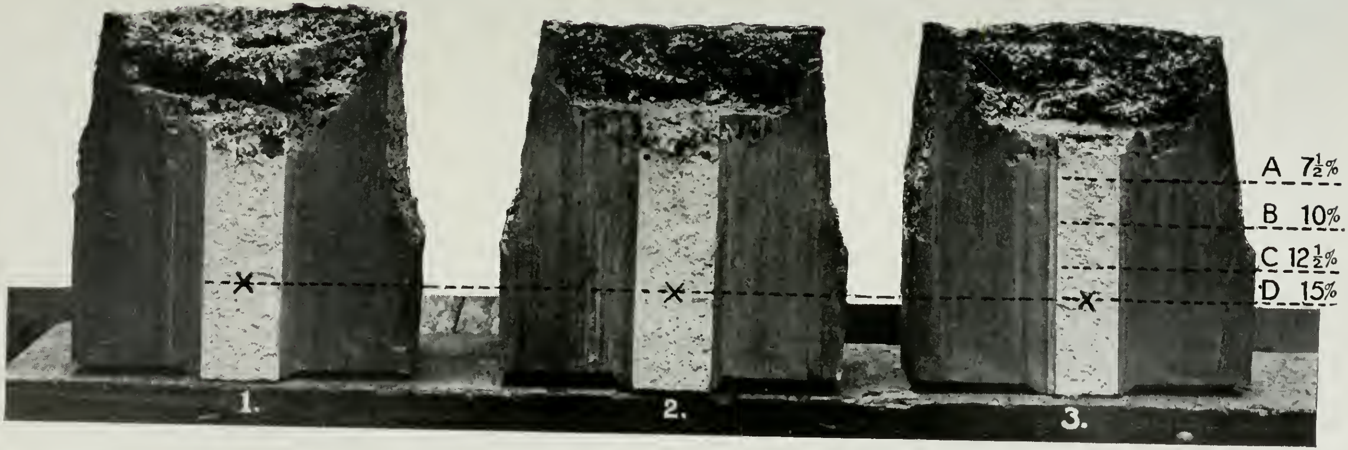
It should be remembered that steel produced from the ingots to be used for the requirements of various governments is most critically examined by many inspectors supervising the material produced and the work done, not on the ingot only, but on each projectile, also including a considerable number of mechanical tests from each ingot, and from a certain number of projectiles made from each ingot. Moreover, each individual ingot is cut up and has to be passed on its own discard; if this were not satisfactory the ingot would be rejected. As pointed out, before the Hadfield system was accepted, more than one hundred ingots were examined in the most severe manner, being cut up from top to bottom. *Every one was found to be satisfactory.*

The following demonstration was made to show the importance and efficiency of the system:

Plate V (photograph No. 2273) shows the upper portion of three 15-inch ingots made under the Hadfield system. This plate shows the soundness and freedom from piping of the ingots. If this is compared with the section of the ordinary rail ingot shown in Plate IV (photograph No. 2221), Fig. B, representing average and current practice, it will be seen how great is the difference. While sound material, whether rails or other articles, can be expected from ingots made as shown in Plate V (photograph No. 2273), it can be well understood that if steel for explosive shell were made from an ordinary steel ingot cast in the usual manner, as shown in Plate IV (Fig. B), there would have to be at least 50 per cent. discard in the ingot, and even then it is doubtful if the material could be safely used.

It must be borne in mind that probably nine-tenths of the ingots used throughout the world, whether for blooms, billets, rails, plates, bars, or other purposes, are made by what is termed "the ordinary method," the result often being not only imperfect but dangerous material.

PLATE V.



The following is the analysis of the material, taken from the ordinary small sample or test ingot:

C	Si	S	P	Mn
.38	.19	.036	.031	.96 per cent.

The following is the analysis on the centre or axis line, as shown by the cross; that is, at the parting line where the 15 per cent. discard was taken:

C	Si	S	P	Mn
.39	.19	.033	.031	.96 per cent.

Similar analyses were also obtained from the 12½ per cent. and 10 per cent. discard lines. It was only when the 7½ per cent. discard line was reached (that is, within one or two inches of the top of the ingot) that the analysis showed any change, namely, as follows:

C	Si	S	P	Mn
.54	.19	.056	.031	.96 per cent.

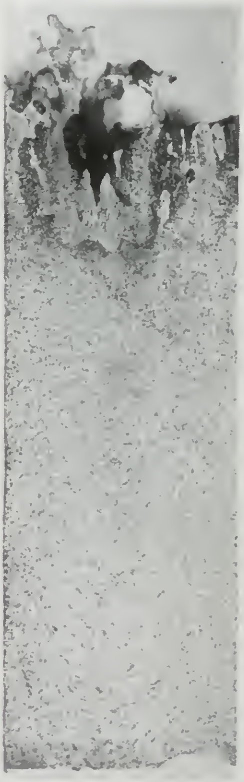
After cutting off 10 per cent. discard from the ingot, the whole of the remaining material is: (*a*) absolutely sound; (*b*) free from blowholes; (*c*) free from segregation.

That portion of the ingot above the transverse section line *A* represents 7½ per cent. discard; *B* represents 10 per cent. discard; *C* represents 12½ per cent. discard; *D* represent 15 per cent. discard.

Photograph No. 2273

To further prove this, Plate VI (photograph No. L.4640) shows an etching of the fractured portion of a 15-inch ingot, marked No. 3 in Plate V (photograph No. 2273) on the centre or axis line, where segregation is usually met with to the greatest extent. This being so sound and free from segregation, it was necessary to continue the etching beyond the fractured portion.

PLATE VI.



Photograph No. L. 4640

The analysis of this particular 15-inch ingot is shown in Table IV. From this table it will be seen that there are no signs of segregation, unsoundness, or piping of any kind until the extraordinarily small discard of 7½ per cent. has been reached. Even in this case the difference in composition is very slight, whereas the composition of an ingot made in the ordinary manner and with only 7½ per cent. discard, to say nothing of the unsoundness, would show probably 0.60 to 0.70 per cent. carbon and 0.07 per cent. each of sulphur and phosphorus.

TABLE IV.

ANALYSIS OF THE 15-INCH INGOT, NO. 3. SHOWN IN PLATE V.

	Analysis				
	C	Si	S	P	Mn
Original steel	.36	.19	.031	.031	.96
A. Discard of 7½ per cent. (sand or feeding head of ingot)	.54	...	.056	.031	...
B. Discard of 10 per cent	.46	...	.040	.031	...
C. Discard of 12½ per cent	.39	...	.040	.031	...
D. Discard of 15 per cent	.39	...	.033	.031	...
E. Bottom of ingot	.38	.19	.031	.031	.96

TABLE V.

SHOWING COMPOSITION OF THE STEEL MADE BY THE SOUND STEEL SYSTEM DESCRIBED IN THIS PAPER.

Table A represents the analyses of drillings from the usual ladle ingot tests

Table B represents the analyses of the same steel, carried out by an independent inspector.

The drillings were taken from the centre or axis line of each ingot, exactly on the parting line of the 15 per cent. discard.

Mark	TABLE A					TABLE B				
	Analyses made by Hadfield of drillings from the usual ladle ingot tests					Analyses made by the inspector from drillings taken from the *centre or axis line* of each ingot after cutting off 15 per cent. discard				
	C	Si	S	P	Mn	C	Si	S	P	Mn
1229	.40	.22	.030	.033	.89	.37	.24	.031	.035	.87
1231	.38	.21	.031	.037	.88	.40	.21	.029	.036	.88
1233	.40	.21	.033	.035	.90	.39	.20	.035	.036	.88
1234	.39	.21	.032	.033	.89	.39	.21	.036	.038	.90
1243	.40	.26	.034	.029	.91	.39	.23	.026	.034	.88
1244	.38	.23	.031	.032	.93	.43	.22	.038	.034	.86
1245	.39	.25	.030	.030	.99	.38	.24	.030	.032	.91
1246	.40	.21	.029	.029	.95	.39	.19	.025	.030	.87
1247	.37	.19	.030	.032	.89	.39	.18	.025	.033	.86
1248	.41	.20	.026	.036	.87	.45	.20	.027	.029	.81

Table V shows a number of analyses taken during the ordinary course of working (that is, they are not in any way special) from the centres of different ingots as above described, the drillings for analysis being taken exactly at the parting line where the 15 per cent. discard has been made. The figures obtained clearly show the important fact that the steel is as pure and free from segregation at this part as it is at the bottom or at any other portion of the ingot.

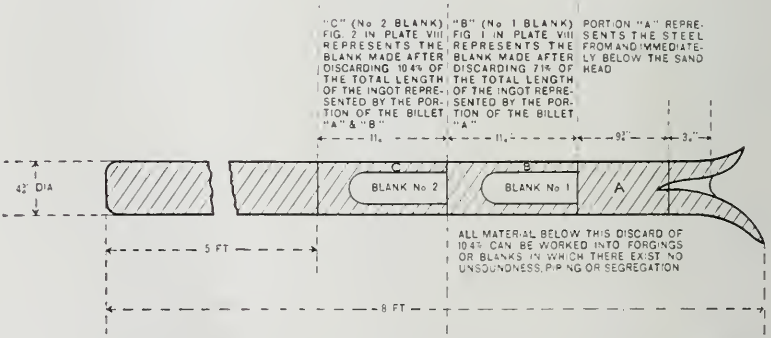
As a further test, the following interesting experiment was made:

The portion of one of the ingots representing the usual 40 per cent. of the discard hitherto demanded in the manufacture of high explosive shell was taken from an 11-inch ingot having the following analysis:

C	Si	S	P	Mn
.38	.18	.024	.035	.85 per cent.

This was forged into a bar 4¾ inches in diameter and about 8 feet in length, as shown by Fig. 7. Projectiles were forged from this bar as follows:

FIG. 7


"C" (No 2 BLANK) FIG. 2 IN PLATE VIII REPRESENTS THE BLANK MADE AFTER DISCARDING 10.4% OF THE TOTAL LENGTH OF THE INGOT REPRESENTED BY THE PORTION OF THE BILLET "A" & "B"
"B" (No 1 BLANK) FIG 1 IN PLATE VIII REPRESENTS THE BLANK MADE AFTER DISCARDING 7.1% OF THE TOTAL LENGTH OF THE INGOT REPRESENTED BY THE PORTION OF THE BILLET "A"
PORTION "A" REPRESENTS THE STEEL FROM AND IMMEDIATELY BELOW THE SAND HEAD
11"
11"
9¾"
3"
4¾" DIA
C
BLANK No 2
B
BLANK No 1
A
5 FT
8 FT
ALL MATERIAL BELOW THIS DISCARD OF 10.4% CAN BE WORKED INTO FORGINGS OR BLANKS IN WHICH THERE EXIST NO UNSOUNDNESS, PIPING OR SEGREGATION

SKETCH SHOWING THE UPPER PORTION OF THE INGOT, FORGED AND DRAWN OUT INTO A BAR 4¾ INCHES IN DIAMETER AND ABOUT 8 FEET IN LENGTH.

It must be borne in mind that this billet is one of several made from the same ingot. In other words, this particular billet represents only the *upper* portion of the ingot.

The material below this billet (that is, representing the ordinary or remaining portion of the ingot) is drawn out into the same kind of billets or bars of the same composition as the other billets, and in these, of course, the whole of the material is used.

The length marked *A* is the portion of the material from the top part of the ingot head which in the writer's system is cast in sand; that is, above the ingot itself. This portion, about 13 inches in length and representing 7.1 per cent. of the discard, was cut off. Below this the projectile forging known as "Blank No. 1" was prepared, as shown by the dotted lines in Fig. 7. Below this, " Blank No. 2 " was taken after 10.4 per cent discard had been allowed. In other words, " Blank No. 1 " was made from the material now not used (that is, after 7.1 per cent. of the whole ingot was discarded), and " Blank No. 2 " after discarding 10.4 per cent.; this is also not now used. The further and following blanks, Nos. 3, 4, and upwards, are not shown, because this is unnecessary, as such blanks then formed part of the current work. As will be seen, even " Blank No. 2 " could also have been safely used.

PLATE VIII.

FIG. 1.

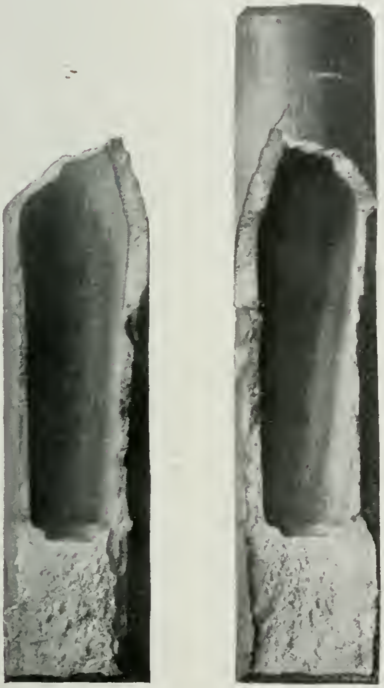
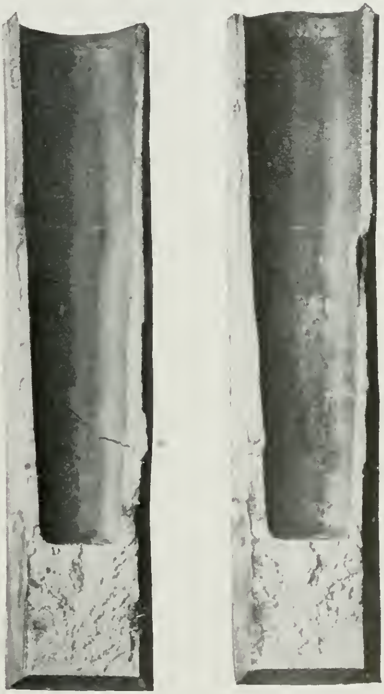


FIG. 2.



Photograph No. 2279

It is remarkable to find that the fracture from " Blank No. 1 " (that is, at the discard of only 7.1 per cent.) was perfectly sound, free from piping, and showed no signs of segregation. In the interior of the blank, after forging, there were some slight skin cracks proceeding from the hollow portion of the ingot top. The projectile from " Blank No. 2 " was perfectly sound in every way, whether as regards surface fracture, freedom from segregation, piping, or any other defects; the interior was also perfectly sound. In other words, from this " Blank No. 2 " (that is, with only 10.4 per cent. discard) a perfectly sound projectile was obtained.

The two projectiles from " Blanks Nos. 1 and 2," after being split open, are shown in Plate VIII (photograph No. 2279). It will be seen that the fractures are sound and that in each case, even including the blank from the portion of the ingot with only 7.1 per cent. discard, the material would have etched quite sound and free from segregation.

As a result of this important research it is thus proved that it is now quite possible to obtain sound ingots which will give perfectly sound billets, blooms, rails, projectiles, etc., and yet with but small discard or loss of material. Therefore, there is effected not only an actual saving in cost of manufacture, but this is also accompanied by the highest quality of product, of a character not obtainable by the processes now used.

American users of rails, therefore, can now obtain material perfectly sound and safe, at the same time, on account of its greater soundness, possessing greater durability than at present, and this can be all accomplished with little or no increase in cost of material.

In conclusion, it will be seen that the case has been proved for the exercise of scientific methods and more care in the manufacture of ingots required for rolling into rails and other shapes, and upon many of which the safety of human life so largely depends. It has also been shown that perfectly sound steel is readily obtainable by methods which can be and are easily applied in practice. As a proof of this, the writer has now produced close upon 40,000 tons of ingots by the plan referred to in this paper. *Every one of these ingots* has been absolutely sound and free from blowholes, piping and segregation. If it is necessary, as most assuredly it is, to obtain sound steel, then it is clear that methods exist which enable this desirable result to be accomplished.

THE PHYSICS OF THE PHOTOGRAPHIC PROCESS.*

BY

C. E. KENNETH MEES, D.Sc.,

Director, Research Laboratory, Eastman Kodak Company.

INTRODUCTION.

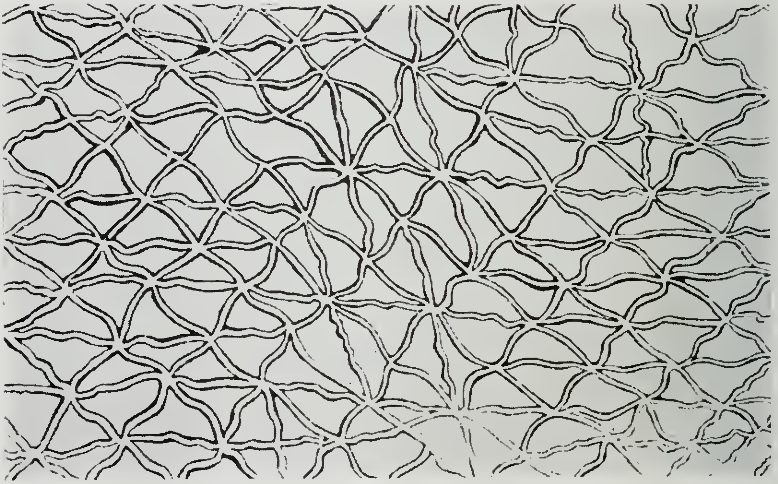
It is curious that, while many books and articles have been written about the chemistry of photography, very little has been written about the physical aspects of the subject, and such discussion as has been published on the physics of photography is chiefly contained in books or periodicals dealing with photographic chemistry, although the importance of the physical aspect of photographic processes completely overshadows the chemical aspect, and our views as to the nature of the reactions undergone on exposure to light and of the relation of the image produced to the exciting cause must be based rather on physical reasoning than on reasoning derived from the chemical standpoint. That this is likely to be the case will be obvious when we consider that photographic sensitive surfaces do not consist of continuous coherent films of homogeneous material, but have a definitely granular structure, the sensitive material itself consisting of grains imbedded in an insensitive matrix, so that in considering the properties of a sensitive material we are considering really the properties of a collection of sensitive grains which may appreciably differ from each other in their individual properties. The properties of such a collection will be the statistical average of the individuals composing it, and in order to understand the properties of a sensitive material we must therefore consider the properties of the individual grains and the relation of their properties to those of the aggregrate material of which they are units. In order to study the properties of the photographic grains, we must first consider their relation to the film in which they occur.

In the typical modern photographic materials this material is a sheet of gelatin, which when dry has a glassy structure and when wet is a jelly. Quincke has suggested that gelatins have a structure similar to that of a sponge, consisting of two phases, the one a phase rich in gelatin and forming the walls of the sponge, and the other a liquid phase very weak in gelatin and filling the cells and passages which are formed by the stiff, strong phase. An attempt to represent this is shown in Fig. 1, while in Fig. 2 is shown the resultant structure which we must assign to a photographic emulsion, with the cells of the jelly filled by granular crystals of silver salt. Thus we see from Fig. 2 and from its enlarged view, Fig. 3, that we may consider an emulsion to consist of crystalline granules of silver bromide inhabiting cells of a jelly which, on setting, surrounds each grain of the silver salt with a wall of gelatin. Of the structure of the grain itself very little is known. In high-speed emulsions it is probable that the grains consist of crystals, while in low-speed emulsions the grains themselves may be partly composed of gelatin separating still finer crystals of silver bromide.

---

* Presented at the meeting of the Photographic Section held Thursday, October 29, 1914.

Fig. 1.



SUGGESTED SPONGE STRUCTURE OF GELATIN.

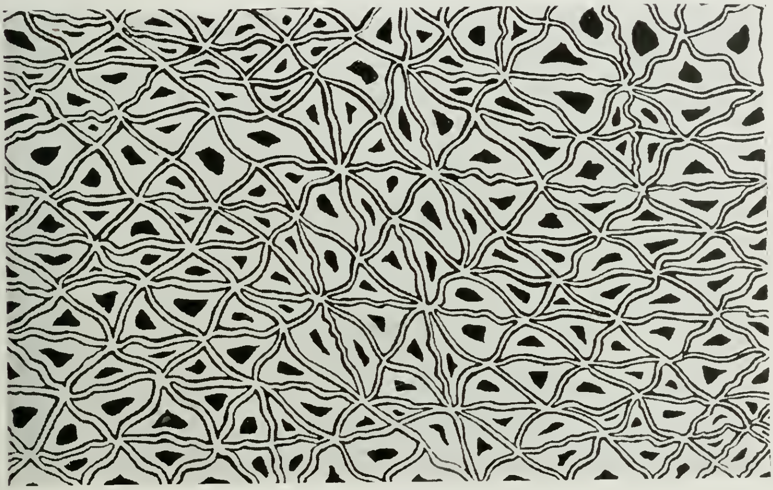
Through the channels in the gelatin, ions and molecules can travel with ease at a velocity comparable with their diffusion rate in water, while penetration through the cell walls is a much slower and more difficult process. Diffusion into gelatin, and especially the diffusion of the developing solution into the emulsion film, may, therefore, be divided into two processes:

(*a*) Macro-diffusion, or the penetration of the solution through the channels of the gelatin; and

(*b*) Micro-diffusion, or the penetration through the walls, which is usually necessary to some extent before the developer can reach the silver halide grains.

When a delivery of goods is made in the city, the transportation to the house is very rapid, but relatively more time is required in getting the goods into the house, and a similar rule holds when a molecule visits the jelly: it travels rapidly through the channels, but slowly through the wall.

FIG. 2.



SILVER BROMIDE GRAINS IN GELATIN.

The Latent Image.—Now, when the developer reaches the grain, reaction takes place, and since reaction occurs only in solution, we must imagine this reaction to be with dissolved, and consequently with ionized, silver bromide, since silver bromide in solution splits up into silver ions and bromine ions. We must consider, therefore, that the silver bromide goes into solution to the extent represented by its solubility product, giving silver ions, and we have

$$AgBr = \overset{+}{Ag} + \overset{-}{Br}$$

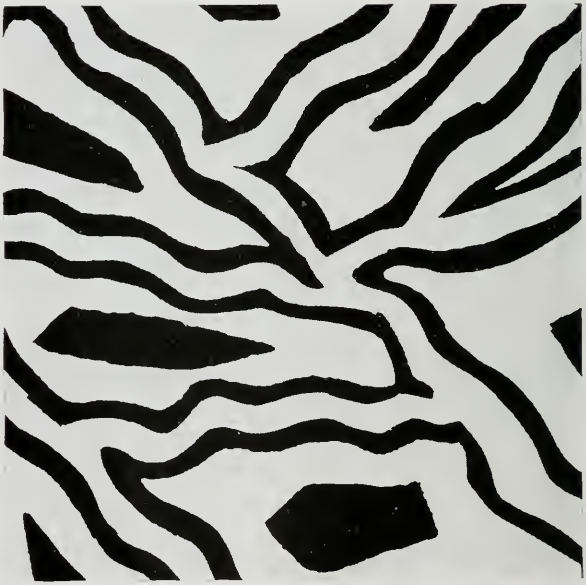
and then, in the presence of a reducing agent, reaction occurs thus:

$$\overset{+}{Ag} + \overset{--}{R} = Ag + \overset{-}{R}$$

the silver ions losing their charge and producing silver molecules in solution.

This will then produce equilibrium unless the silver can precipitate, in which case more silver bromide will dissolve, which will precipitate as metallic silver in turn, and the reaction will proceed until the whole grain is dissolved and converted into metallic silver.

Fig. 3.



ENLARGED VIEW OF FIG. 2.

Suppose, however, that the silver cannot precipitate; then, since the solubility of the silver bromide is very small, the liquid around the grain will very soon be saturated and reaction will stop unless precipitation occurs. Now, precipitation in a saturated solution depends chiefly on the presence of a nucleus; for instance, a hot saturated solution of thiosulphate of soda can be kept for a long while without precipitating unless a nucleus of some kind is introduced. If anything which can form a nucleus be introduced, however, the whole of the solution will go solid with the precipitation of the thiosulphate.

In the same way, if a nucleus of any kind be present in a sensitive grain, then on development silver will be deposited on the nucleus, more silver bromide will be dissolved, reduced, and deposited in turn, until the whole silver bromide grain has been transformed into metallic silver. When a grain once starts to develop, it will always completely develop, provided that it is supplied with sufficient developer and given sufficient time. Moreover, there is very little transference of silver bromide in solution from one grain to another; that is, the silver which forms a grain in the finished image is derived from the grain of silver bromide in that place and not from any other grains near by.

This has always been assumed, but the best proof of it was given by Kinoshita,[1] who showed that when alpha particles fell upon a photographic emulsion each particle made the grain which it struck developable, so that one grain of silver bromide was obtained for each alpha particle falling upon the plate.

In addition to light, other materials can produce a nucleus in the grain. For instance, treatment with auric chloride solution will produce a nucleus of metallic gold, and on adding developer to an emulsion treated with auric chloride all the grains will develop together, showing that a nucleus has been produced in every grain.

The action of light on the photographic emulsion has always been stated to produce a latent image, which by development was transformed into an image of silver, and the search for the philosopher's stone of photography has been that for the nature of this latent image, which from the earliest days has been the subject of continual speculation. The chemists at first thought that, since the long-continued action of light on silver bromide liberated bromine, the latent image must be a halide of silver, containing less silver than silver bromide, and ascribed to this the constitution Ag_2Br, which was termed silver sub-bromide.

Abegg considered the latent image to consist of a nucleus of metallic silver forming a solid solution in the silver bromide. Some other chemical theories of the latent image have also been suggested. An objection, however, that applies to all these theories is that the energy available during exposure is not sufficient to produce an appreciable amount either of metallic silver or of silver sub-bromide from silver bromide. This was first pointed out by Hurter, who, from a consideration of the amount of energy which was liberated in the burning of a candle, came to the conclusion that the available energy was not 1 per cent. of that necessary to reduce to silver sub-bromide the silver grains which eventually proved to be developable. From this standpoint of available energy, the nature of the latent image can be attacked with results which, while not definitely making certain what its constitution must be, limit us in our conclusions so greatly that we find it necessary to abandon all ideas of a latent image consisting of grains materially different from silver bromide. The only means by which we can recognize the difference of exposed from unexposed silver bromide is by treating it with a developer, whereupon the exposed silver bromide is reduced, while the unexposed silver bromide is not. The difference between the two can be lessened and finally destroyed by the action of oxidizing substances, such as chromic acid. These are almost the only chemical facts which we have to guide us in our decision as to the nature of the latent image; that is, as to what happens to silver bromide when it is exposed to extremely small quantities of light energy. If the exposure is to large quantities of light energy, there is no doubt as to what happens. Bromine is given off, and the residue must consist either of silver sub-bromide or of a mixture of silver bromide and silver. The following statement, for which I am indebted to Dr. P. G. Nutting, as to the energy involved in the exposure of a high-speed photographic emulsion, would seem to suggest that, from a physical point of view, at any rate, and, therefore, from the chemical, it is quite certain what happens when the latent image is produced by a minimum exposure to light, and that the change is really the unit change that can be suffered by any substance when acted on by energy.

---

[1] Proceedings of the Royal Society, A 83 J. 432, 1910.

Consider the exposure to light which is sufficient after full development to produce a deposit of unit density; that is, one which will transmit one-tenth of the incident light.

A deposit which has this density contains ten milligrammes of metallic silver per square decimetre, or one-tenth milligramme per square centimetre, which represents roughly 10^{19} molecules of silver, or 10^7 grains 3μ in diameter. Now, the energy of the amount of violet light required to give an exposure necessary to make an emulsion film developable to this density, is of the order of 10^{-7} ergs per square centimetre. Therefore, each grain (which contains, on the average, 10^{12} molecules) receives 10^{-14} ergs to make it developable. Now, we know that, in order to detach one electron from a molecule, 5×10^{-12} ergs are required in the separate molecules of gas. This is a maximum amount, and it is possible that in the exposure of a photographic plate 10^{-14} ergs are sufficient to detach one electron. Clearly, then, the energy incident on a grain during exposure may be sufficient to affect only one molecule in that grain, and the latent image may be composed of grains in each of which, on the average, only one molecule has lost an electron by the action of light.

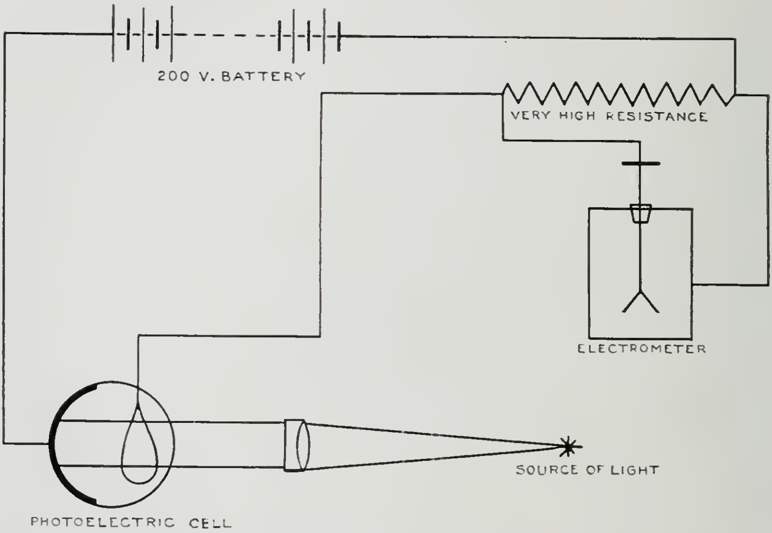
Now, if the action of light on the emulsion is to liberate an electron from the grain, its action is entirely analogous to that which light has on so many materials, the action which is termed the photo-electric effect, and Joly's suggestion, put forward a number of years ago,[2] that the exposure of a photographic emulsion is photo-electric in its nature, seems to be coming within reach of proof. If a beam of light falls on to a metallic surface which is attached to a negative pole of a battery, then, if the frequency of the light waves is high enough, electrons will be liberated from the metallic surface, and under the impressed voltage will be shot off with considerable velocity. A customary form of apparatus is shown in Fig. 4, the light here being shown as falling on an evacuated cell containing a surface of potassium metal, the number of electrons liberated being measured by the accumulated charge on the electroscope.

One of the most typical things about the photo-electric effect is that in order to produce any photo-electric effect the light must have a frequency above a certain critical value, this critical value depending upon the surface employed. The same is true of photographic emulsions. Fig. 5 shows the sensitiveness curve of silver chloride and silver bromide, and from this figure it can be seen that there is a critical value of the wave length, about $400\mu\mu$ for silver chloride and $480\mu\mu$ for silver bromide, above which the sensitiveness is extremely small and below which the sensitiveness for uniform energy is uniform. Photo-electric cells, by special treatment of the surface, can be made to change their distribution of spectral sensitiveness, and in the same way photographic emulsions, by treatment with suitable dyes, can be made sensitive to regions of the spectrum other than those to which they are normally sensitive, the necessary conditions for the sensitizing dye being that it shall absorb in the region for which it is to sensitize, and that it shall dye the silver bromide itself, and not merely the gelatin. These conditions are by no means sufficient, as only two main groups of dyestuffs sensitize to any great extent, these being the fluoresceins and a group of complex quinoline derivatives.

---

[2] *Nature*, 72, p. 308, 1905.

Fig. 4.

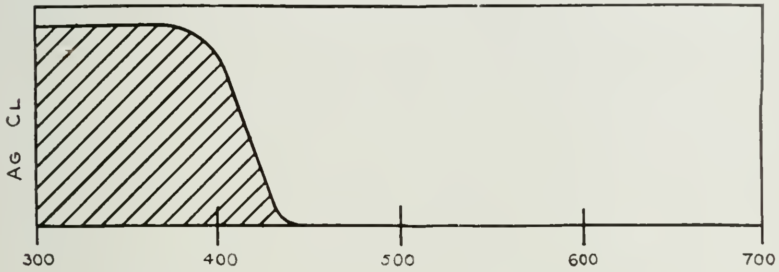


APPARATUS FOR DEMONSTRATING THE PHOTO-ELECTRIC EFFECT.

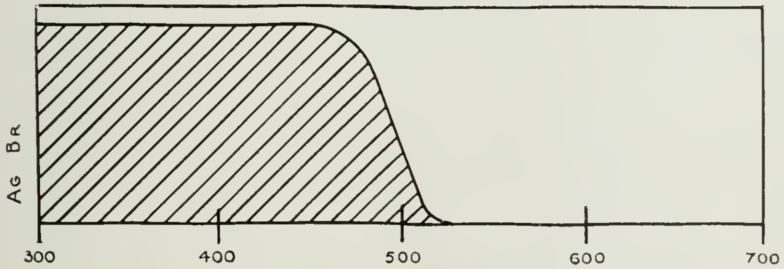
Reversal.—If for a photographic emulsion we plot a curve of the density against exposure, using for convenience a logarithmic scale of exposure, then at first the density increases rapidly with exposure, after a time increases less rapidly, and finally ceases to increase at all, and then, after a period begins to decrease somewhat, and finally, with very great exposures, again increases slightly (Fig. 6). This decrease in density with prolonged exposure is known as reversal, and any theory of photographic action must attempt to explain the region of reversal.

H. S. Allen, in his interesting monograph on photo-electricity,[3] suggests that the electrons expelled from the silver bromide may become attached to molecules of the surrounding gelatin, and if these molecules are now affected by external stimulus, such as radiation of longer wave-length, the electrons will be enabled to enter again into combination with the atoms from which they were liberated, this recombination being effected by the electrostatic forces between the oppositely charged particles. If recombination is not assisted in this way, the electrostatic field will increase under the continued action of light, and self-neutralization will take place, as was suggested by Joly.

FIG. 5.



SENSITIVENESS OF SILVER CHLORIDE TO THE SPECTRUM.



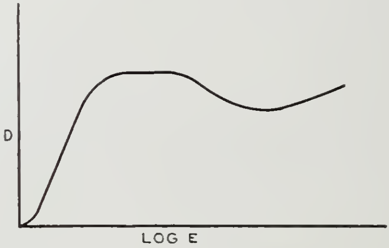
SENSITIVENESS OF SILVER BROMIDE TO THE SPECTRUM.

Now, while this explanation of reversal may be a possible one, I am a little skeptical about it, and it seems to me more likely that under the continual influence of light the silver bromide is broken up into metallic silver and bromine, as it is well known to do, the bromine given off from a much-overexposed plate being easily smelt. Now, bromine actually attacks exposed silver bromide, preventing it from being developed, so that it would seem likely that grains which have been completely decomposed by light, liberating the bromine, would be less easily developable than those which had simply suffered the photo-electric change to the latent image. The gain in density which is observed with still more extended exposure may be ascribed to the actual production of metallic silver by the long-continued action of light, and, indeed, such reduced silver can be shown to exist by fixing the exposed but undeveloped plate. We may, therefore, consider that there are probably three stages in the action of light on the photographic film: first, the photo-electric effect producing the latent image; second, dissociation of the silver bromide involving liberation of bromine and destruction of some of the latent image produced; and, finally, visible blackening by the liberation of metallic silver.

---

[3] Longmans, Green & Co., 1913.

Fig. 6.

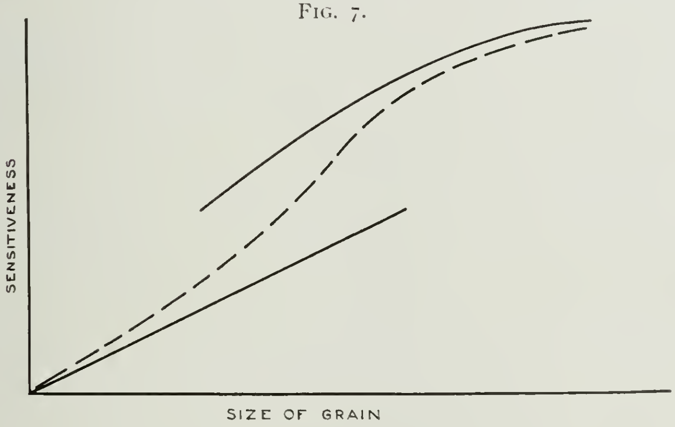


Density-exposure curve showing reversal.

The Effect of the Variation of Grain Size on Various Properties of Photographic Materials.—Very little has been published on the effect of the difference in the size of grain of different emulsions upon their properties. Four different aspects of the question have to be considered. The first is the effect of grain size on sensitiveness; second, the effect on gradation; third, the effect on the color of the silver deposit; and fourth, the effect on the resolving power.

Now, from the earliest days it has been known that the more the size of the grain increased the more sensitive the emulsion, and that the grain of high-speed emulsions was coarser than that of low-speed emulsions; but it has not been so generally recognized that the difference between high- and low-speed emulsions is not simply one of size of grains, but that there is a qualitative difference between them which must be due to the nature of the grain. Thus it might be assumed that if we took an emulsion, starting with a very fine grain, and cooked it, we could increase the sensitiveness uniformly, as is shown in the dashed curve of Fig. 7. Actually, however, if we start with a very fine-grained emulsion and cook it, the size of grain and the sensitiveness only increase to a certain limited extent, as is shown in the lower solid curve, and in order to get a high-speed emulsion having larger grains and much greater sensitiveness, we must start in an entirely different manner, precipitating the silver of medium grain, which can then be increased in size with a concomitant increase of sensitiveness, as is shown in the upper solid curve, and no direct transformation of an emulsion which has been ripened from a very fine grain into a high-speed emulsion seems to be possible. The difference may be that in the low-speed type the silver grain consists of a network of crystals containing gelatin, while in the high-speed emulsions the gelatin is distinctly separated from the crystals, so that in a low-speed emulsion each of the crystals forming part of the grain must be made developable by the action of light, while the large grain of the high-speed emulsions requires action only at one point to make it entirely developable, so that the energy required to form a latent image in a high-speed emulsion is only that necessary for the liberation

FIG. 7.



GROWTH OF SENSITIVENESS WITH SIZE OF GRAIN.

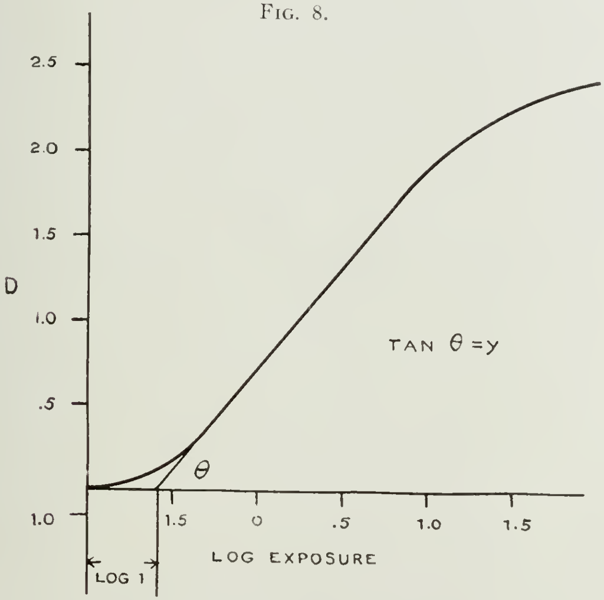
of one electron per grain, while in the low-speed emulsion several electrons for each grain may be necessary.

Considering, first of all, the effect of size of grain on the sensitiveness of high-speed emulsions, let us assume that the amount of energy required to make any grain developable is the same, whatever the size of the grain. Now, it has been shown, both experimentally and theoretically, that the density is equal to a constant times the mass of silver per square centimetre, the constant applying only to different densities in the same emulsion, though it varies very little throughout all high-speed emulsions, the value being approximately 1/10 mg. per square centimetre for a density of unity.

Now, since the mass of silver is equal to the number of grains multiplied by the cube of the diameter, and if all the grains, whatever the diameter, required the same amount of energy to make them developable, then for two given exposures on different sizes of grain the density produced for a given exposure will vary as the cube of the diameter of the grain.

In high-speed emulsions, grains vary in diameter from about 1 to 3μ, so that this mere variation of size, without any difference in the sensitiveness of the single grains, would give a range of sensitiveness from 1 to 27 in high-speed emulsions, supposing that these emulsions can be made homogeneous. Inasmuch as the emulsions are not homogeneous, but each emulsion will contain grains of all sizes, the sensitiveness will depend upon the distribution of the different sizes of grains, and so also will the shape of the plate curve, this plate curve being the relation between the density and the logarithmic exposure. This curve was first plotted by Hurter and Driffield, and afterwards by Eder, both of them terming it the characteristic curve of a plate. It has the shape shown in Fig. 8. It will be seen that throughout a considerable portion of the curve the density is proportional to the logarithmic exposure, and through this portion the range of light intensities in the original is correctly reproduced by the absorption of the negative. At the beginning of the curve, in what is termed the period of under-exposure, the density rises less rapidly than the logarithmic exposure, and at the top of the curve, in what is termed the period of over-exposure, the density fails to rise in the correct proportion, and finally becomes constant, this constancy continuing for a long period, after which reversal sets in, as has previously been explained. Now, the shape of this curve depends to a considerable extent on the distribution of the different sizes of grain in the emulsion. With a homogeneous emulsion we should have a simple curve with short over- and under-exposure portion, as shown in Fig. 9, and by adjusting the sizes of grain so that there is a sufficient number of grains distributed around the mean we can diminish the size of the under-exposure portion and obtain a longer straight line (Fig. 10). We can, therefore, form a mental picture of the relation between the distributions of the grain and the sensitiveness curve. Up to the present there has been very little experimental work done on this subject, the work having only just been commenced, but I venture, in Figs. 9, 10, and 11, to show what I consider may be the relation between some distributions of grain and the resultant sensitiveness curves.

FIG. 8.

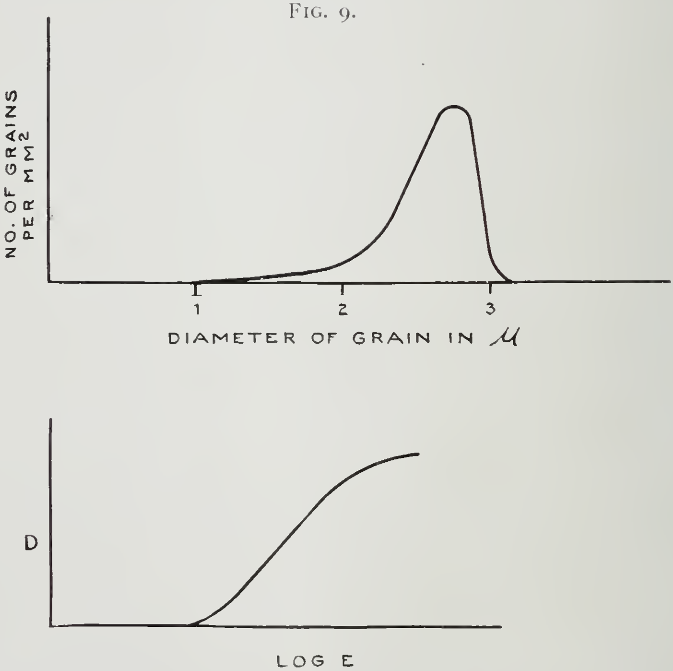


CURVE SHOWING RELATION BETWEEN DENSITY AND EXPOSURE.

Fig. 9 shows the case of an approximately homogeneous emulsion with a mean grain size of about 2.6μ, the upper curve showing the number of grains of each size in a given area plotted against their diameters. Such an emulsion gives a curve with a short straight line, little under-exposed portion, and a low inertia, the curve being well to the left.

In Fig. 10 a much less homogeneous emulsion is shown, the larger grains being of the same size as those in Fig. 9, but the average grains being only about 2.2μ, and the emulsion containing a much larger proportion of small grains. The result of this is that, while the lowest densities are obtained at the same point as the emulsion shown in Fig. 9, the inertia is somewhat greater and the straight line is much longer, the large number of small grains enabling the density to go on growing with the exposure after a homogeneous emulsion has all its grains exposed.

FIG. 9.

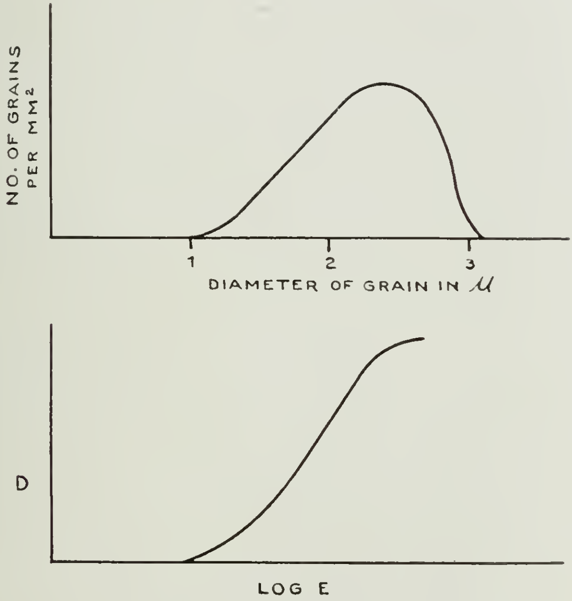


D-LOG E CURVE AND GRAIN DISTRIBUTION CURVE (1).

In Fig. 11 a distribution of grains is seen resulting from the mixture of two different emulsions, one a low-speed, fine-grained emulsion, and the other a high-speed, coarser-grained emulsion; the resulting curve again shows the commencement of action at the same point, but now we have a very long under-exposure portion, due to the large grains, and then a straight line, due to the finer-grained portion of the emulsion.

Turning to the question of the effect of grain size on low-speed emulsions, the first effect is on covering power; that is, on the amount of density that can be obtained from a given weight of silver. Clearly, the smaller the grain, the greater the surface for a given mass, and consequently the greater the covering power, so that the finer-grained emulsions will require less silver than coarse-grained. As in the case of high-speed emulsions, the sensitiveness of low-speed emulsions is, to some extent, dependent on the sizes of the grain, but it is improbable that in the case of the low-speed emulsions we can trace so simple a relation between the sensitiveness and size of grain as we should be able to with the high-speed type. In the high-speed emulsions, as has previously been explained, there is some justification for assuming that the amount of energy required by an individual grain to make it developable can be considered a constant quantity, it being that necessary to liberate an electron; but in the low-speed

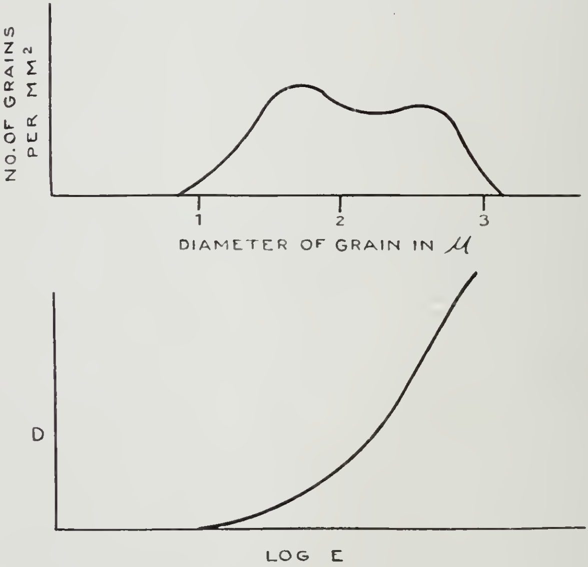
FIG. 10.



D-LOG E CURVE AND GRAIN DISTRIBUTION CURVE (2).

emulsions the grains are very complex, and, as the complexity will vary from grain to grain, we have no right to assume that the same amount of energy will make different grains in low-speed emulsions developable. The complex grains of low-speed emulsions may, for instance, require a unit quantity of energy for each separate unit of the complex, in which case the amount required will vary from grain to grain throughout the emulsion, and the sensitiveness of the emulsion will depend not only on the size of the complex grains but on their complexity.

Fig. 11.



D-LOG E CURVE AND GRAIN DISTRIBUTION CURVE (3).

Another effect of the size of the grains in low-speed emulsions is the effect on the color of a deposit. If the silver grains, after development, approximate in diameter to half the length of a light wave, then they will have a selective absorption for light of wave-lengths approximately twice their diameter, and the silver deposit will consequently appear colored. Such colored deposits can be obtained with slow developing papers or lantern slides by using a developer in which the deposition of the silver is restrained by the addition of silver solvents, so as to produce a very slow deposition from a solution rich in silver. The result is to produce colors which, though not brilliant, are yet distinctly pleasing.

Resolving Power.—In many applications of photography it is necessary to get as sharp images as possible, and the inhomogeneity of the sensitive film has always been a source of distress in some classes of work, because of the way in which the silver image is broken up by the grains composing it. The relation, however, between the fineness of detail that an emulsion can give and the size of the grains is not quite as simple as it appears at first sight.

This subject was first studied by Wadsworth, and, in view of his work, the matter is discussed by Baly.[4] Baly states that it can be assumed that on a negative two lines can be separated if between the grains at the maxima of the lines there are one silver particle and two spaces, so that in photographic resolution it is necessary that the linear distance between the centres of the lines should be four times the diameter of a grain. Now, inasmuch as the diameters of grains are from 1 to 3μ (Baly wrongly states them to be from 5 to 25μ), this rule should give us a resolving power of from 4 to 12μ, an amount which is much above that found in practice.

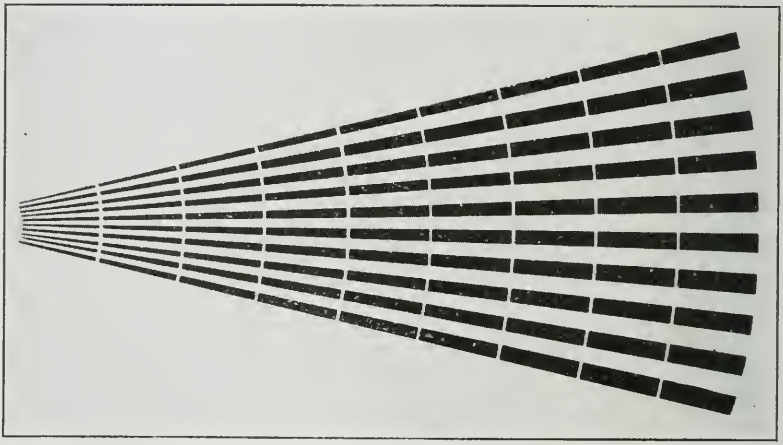
The writer started work on this subject in 1907 in the following manner: A tube about twenty feet long was taken, and at the end of this the object was placed; at the other end was fastened a small camera made of a heavy brass tube, to which was bolted a brass face plate, against which the face plate of a plate holder could be placed. This camera carried the lens in a very solid mounting, this being a spectroscope objective of high aperture which on test worked up to its theoretical resolving power. The first object photographed was a small slit covered with a black wedge so as to get a gradation of intensity down the slit, but it was soon clear that it would be better to have a numerical expression of resolving power, and at first this was done by photographing line gratings with different sizes of lines until one was found which would only just resolve. Finally, however, a converging grating was made as shown in Fig. 12, and by photographing this the point could be observed in the photograph at which resolution first occurred, and, as the spacing of the grating was known, a numerical expression for resolving power could be found. While this method is still convenient for the practical testing of emulsions, it introduces a number of systematic errors which prevent it being suitable for a final investigation as to the nature of resolving power.

---

[4] "Spectroscopy," Longmans, Green & Co., p. 330.

Goldberg[5] took up the subject by printing contact images of small apertures on the plate. He showed that there were two factors in the resolving power: one an optical factor, which he termed the turbidity factor, depending on the scattering of the light in the emulsion, and the other the photographic factor, which gives the translation of the distribution of light in the emulsion into the distribution of silver after development.

FIG. 12.



RESOLVING POWER TEST OBJECT.

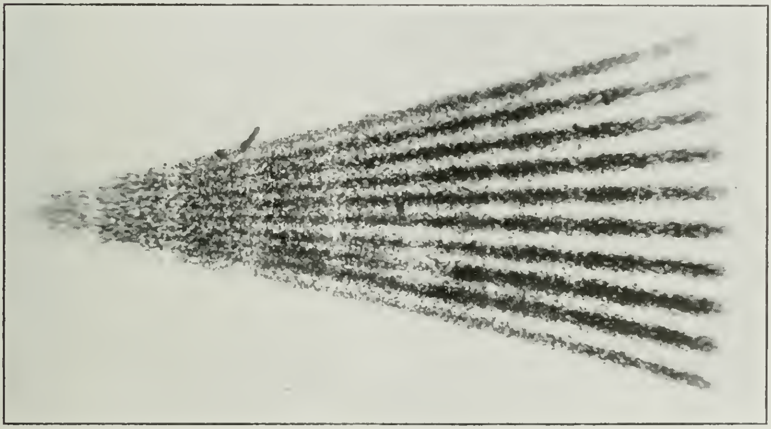
The subject has again been taken up in our laboratory by Dr. Nutting,[6] who, instead of using apertures, has printed images of the edge of a steel blade on the plate by parallel light, and this work is still going forward on the experimental side. Dr. Nutting points out that the optical factor of turbidity can be split into two separate factors: the one the turbidity of the emulsion in the strictest sense, that is to say, its scattering power for light, and the other the opacity of the emulsion or its stopping power for scattered light. An emulsion having high turbidity and low opacity will have a very low resolving power; on the other hand, even if the emulsion has high turbidity, if its opacity is also high, its resolving power may be good. A typical example of this is the wet collodion plate, in which the turbidity is considerable, but where the opacity of silver iodide for blue-violet light is so great that the resolving power is very high. In a Lippman emulsion the resolving power is high if the emulsion is very clear, because the turbidity is very small, but the opacity is also small, and the slightest increase in turbidity may make the resolving power very low. An interesting experiment which I have made was as follows: I made a Lippman emulsion, coated it, and found the resolving power, which was very high. Some of the emulsion was slightly warmed so that it increased in speed somewhat and showed slight turbidity, and, although the increase in speed was quite small, the resolving power was now very poor. By further heating the emulsion so that it became visibly opaque, with a considerable increase of speed, although the turbidity was now high, the opacity had risen sufficiently to give the emulsion a considerably better resolving power than after the first heating had taken place. The relation of the resolving power of emulsions to the size of the grain may, therefore, be roughly expressed somewhat as shown in Fig. 14.

---

[5] *Photographic Journal*, November, 1912.

[6] *Photographic Journal*, June, 1914.

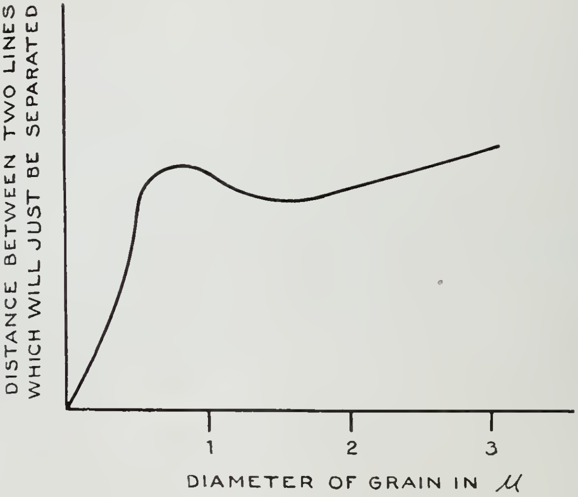
FIG. 13.



REPRODUCTION OF TEST OBJECT ON A PLATE.

The distance between the two lines which will just be separated with a given emulsion will be extremely small for extremely small sizes of grain, because such sizes of grain far below the wave-length of light will scatter very little light: that is, the turbidity will be negligible. As the size of grain rises, however, the turbidity increases very rapidly, and with it the distance necessary to separate two lines, until with a grain diameter a little less than 1μ the turbidity is high and the opacity still low, so that the necessary separation of the lines is a maximum, and then, as the grain still grows, the opacity grows faster than the turbidity and the lines to be separated can be somewhat closer together. Then, again, with the increasing diameter of the grains the actual space factor comes in, the size of the grains themselves and the distance between them becoming comparable with the distance between the separated lines, and with increasing size of grain this distance must again increase steadily. It must be understood that Fig. 14, like the other figures occurring in this paper, is not intended to be drawn to scale or to be a quantitative representation in any way. It is simply an illustration of the general trend of the effects, being a purely general curve drawn free-hand in the absence of any quantitative data.

Fig. 14.



Resolving power and grain size.

ON THE BOILING-POINT OF AQUEOUS SOLUTIONS OF NITRIC ACID AT DIFFERENT PRESSURES. PART I.*

BY

HENRY JERMAIN MAUDE CREIGHTON
Member of the Institute,

AND

JOHN HORACE GITHENS
Department of Chemistry, Swarthmore College.

INTRODUCTION.

The composition of the vapor formed by the evaporation of a mixture of two liquids depends upon the proportion in which the components are contained in the mixture, and upon the individual vapor pressures of these components at the temperature at which evaporation occurs. The vapor pressure of each component of a liquid mixture is always less than the vapor pressure of the component in the pure state; but whether, in the case of infinitely miscible liquids not closely related, the total vapor pressure of the mixture is greater or less than that of either of the pure components depends upon the proportions in which they are present, upon the relative attraction between the like and unlike molecules, and upon the solubilities of the vapors in the unlike components of the liquid mixture. For a mixture containing two liquids, A and B, the dependence of the vapor pressure of the mixture upon the solubility of the vapors in the liquid may be illustrated by three well-known cases: when the vapor of A is but slightly soluble in liquid B and that of B but slightly soluble in liquid A, the vapor pressure of the mixture is greater than the square root of the product of the vapor pressures of the two components; when the vapor of A is soluble in liquid B and that of B soluble in liquid A, the vapor pressure of the mixture is less than the square root of the product of the vapor pressures of the two components; and, thirdly, when the vapor of A is but slightly soluble in liquid B and that of B soluble in liquid A, the vapor pressure of the mixture is equal to the square root of the product of the vapor pressures of the two components. In the second of these cases, the component which is in excess evaporates more rapidly than the other, and there is finally left behind a residual mixture which evaporates unchanged in composition; *i.e.*, a mixture of minimum vapor pressure.

---

* Communicated by Professor Creighton.

The occurrence of mixtures of maximum boiling-point (minimum vapor pressure) is fairly rare. In the majority of cases where the formation of such mixtures has been observed, one of the components is an acid and the other a base or a liquid of basic character. Among the more common examples of mixtures of maximum boiling-point are aqueous solutions of most of the strong mineral acids.

The composition of the mixture of maximum boiling-point of nitric acid and water has been investigated at different pressures by Roscoe,[1] who has shown that aqueous solutions of nitric acid of widely different degrees of concentration attain on boiling, at atmospheric pressure, a mean composition of 68 per cent. real acid. When aqueous solutions of nitric acid are heated under diminished pressure, Roscoe has shown that, at 70 mm. of mercury, a residual liquid having a constant mean composition of 66.7 per cent. of nitric acid is obtained, while under a pressure of 150 mm. of mercury equilibrium occurs when the percentage of nitric acid in the residual mixture reaches 67.6. At 1260 mm. of mercury he has found that the mixture of maximum boiling-point contains 68.8 per cent. of acid. It will be seen, from the foregoing figures, that the acid content of the mixture of maximum boiling-point increases slightly with pressure.

When, for a constant pressure, the boiling-points of mixtures of two components which form a mixture of maximum boiling-point are plotted on the axis of ordinates against the percentage of one of the components of the mixture on the axis of abscissæ, the curve obtained rises gradually as the percentage of the component increases, reaches a maximum, and then rapidly declines. The composition of the mixture corresponding to the maximum of the curve is that of the mixture of maximum boiling-point. It is our intention to determine and study the boiling-point curves of aqueous solutions of nitric acid over a large range of pressure, and to ascertain, from the positions of the maxima of the curves, how the composition of the mixture of maximum boiling-point changes with pressure.

The present communication deals with the results of measurements made at atmospheric and diminished pressures.

---

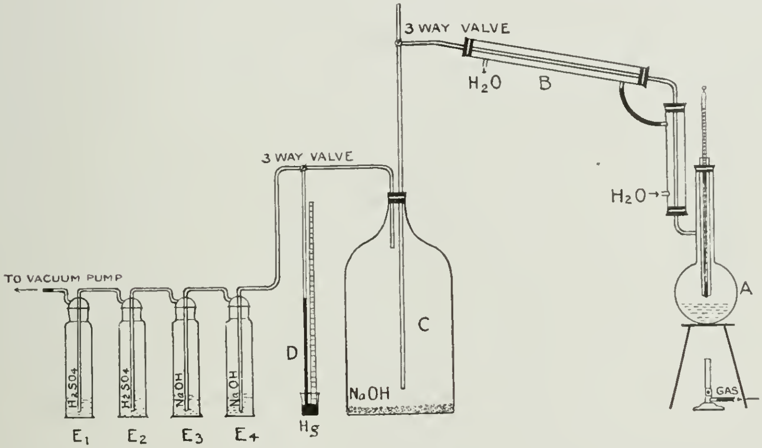
[1] Roscoe, H. E., *Journ. Chem. Soc.*, 13, 146 (1861).

EXPERIMENTAL.

The boiling-points and vapor pressures of mixtures of nitric acid and water were determined by the dynamical method.

The flask in which the aqueous mixtures of acid were heated was similar to that described[2] by Young. To the wide, long neck of a flask having a capacity of 200 c.c. a side-tube is sealed. This side-tube is bent upwards at right angles about 10 cm. from the neck of the flask, and the vertical portion cooled by a water-jacket so that it acts as a reflux condenser. The end of the wide neck of the flask is provided with a well-fitting cork, through which passes a narrower, thin-walled glass tube which has a hole blown in it a little below the cork. This narrower tube is also closed with a cork, through which passes a thermometer graduated in $^1/_{10}$ °. This flask is shown in Fig. 1, at *A*.

FIG. 1.



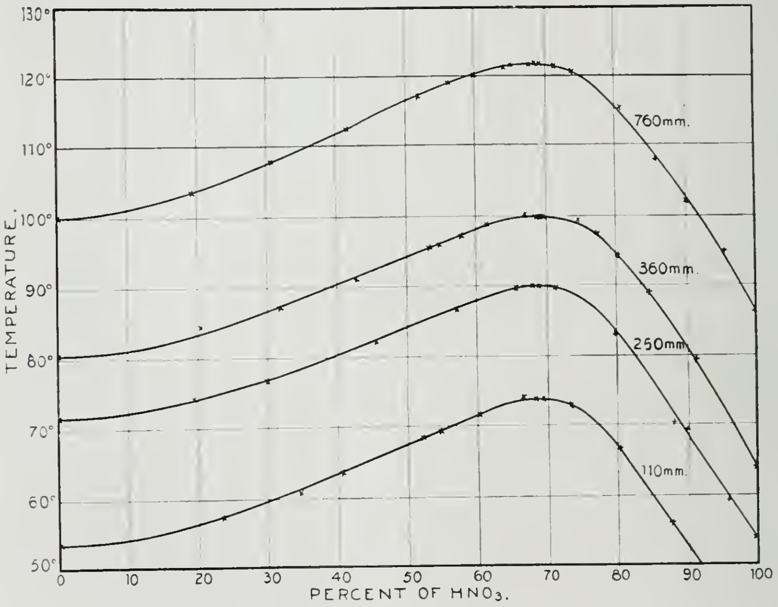
As it is important that the volume of the vapor should be relatively small to that of the liquid, the flask is filled to two-thirds its capacity. The thin-walled tube is pushed down until the bottom is about 3 mm. above the surface of the liquid. The end of the bulb of the thermometer is about level with the bottom of the thin-walled tube.

As Young points out, this apparatus possesses the following advantages: "(1) The liquid that returns from the reflux condenser cannot come near the thermometer, and the amount of liquid which condenses on the thermometer and on the thin walls of the thin-walled tube is exceedingly small; on the other hand, with the large quantity of liquid which is present and the small flame that is required there is no fear of the vapor being superheated. (2) It is possible to take readings of the temperature of the vapor and of the boiling liquid without altering the position of the thermometer, for when the burner is directly below the centre of the bulb the liquid boils up into the thin-walled tube well above the thermometer bulb, but when the burner is moved a little to one side the surface of the liquid immediately below the thin-walled tube remains undisturbed and the liquid does not come in contact with the thermometer bulb." The values for the boiling-points given in the following tables refer to the temperature of the vapor immediately above the boiling liquid.

---

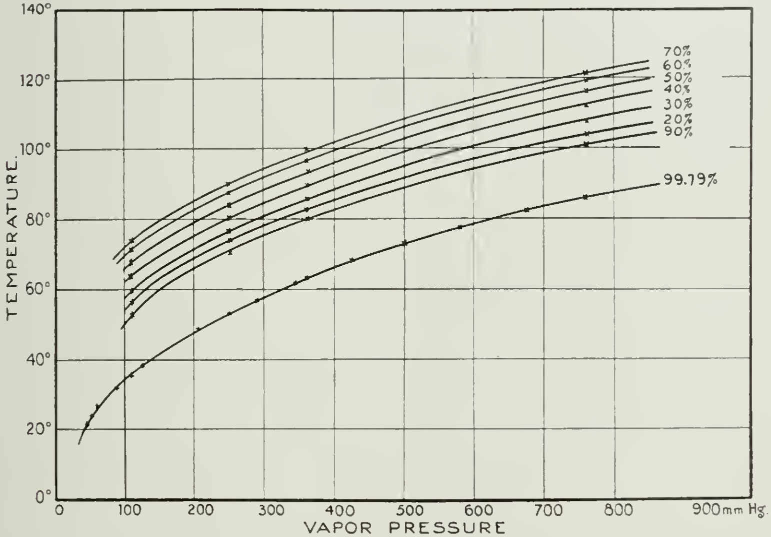
[2] Young, S., *Journ. Chem. Soc.*, 81, 772 (1902).

Fig. 2.



The apparatus described above was employed to determine the boiling-points at atmospheric pressure, and from the values obtained the boiling-points at 760 mm. pressure were calculated.[3] In all boiling-point determinations the thermometer readings were corrected for the cooling of the mercury thread which extended above the top of the neck of the flask.[4] When boiling-point determinations were made at diminished pressure, the apparatus shown in Fig. 1 was employed. In this figure, *A* is the boiling flask previously described; *B* is an additional reflux condenser; *C* is a bottle with a capacity of 30 litres, the bottom of which is covered to a depth of several centimetres with a solid sodium hydroxide; *D* is a mercury manometer, and E_1, E_2, E_3, and E_4 are wash bottles which remove the last traces of nitric acid and water from the gas before it passes to the Geryk pump used for evacuating the apparatus. Bumping was practically prevented by placing several sharp pieces of platinum at the bottom of the boiling flask. The aqueous solutions of nitric acid were heated to boiling, and, after the boiling-point became constant, the liquid remaining in the flask was quickly cooled and its nitric acid content determined by analysis.

FIG. 3.



Before studying the boiling-points of mixtures of water and nitric acid, a number of measurements were made of the boiling-points of pure nitric acid at different pressures. Pure acid was obtained by distilling a mixture of equal volumes of concentrated sulphuric acid and c. p. nitric acid under reduced pressure, and then redistilling the distillate thus obtained with an equal volume of concentrated sulphuric acid. The second distillate, which was yellow in color, was gently heated to 45°, after which a current of pure, dry air was bubbled through the acid until it became cold. By this means practically all the dissolved nitrogen peroxide was removed and an acid having a pale lemon color was obtained. The density (*in vacuo*) of this acid was $d\frac{25^\circ}{4^\circ} = 1.5049$. Analysis showed that the acid contained 99.79 per cent. HNO_3. In Table I is shown the boiling-point of this acid at a number of different pressures. The change in vapor pressure of pure nitric acid with temperature is shown graphically in Fig. 3.

---

[3] Kahlbaum, G. W. A., *Ber.*, **19**, 3101 (1886).

[4] Rimbach, E., *Ber.*, **22**, 3072 (1889).

Table I.

99.79 per cent. HNO_3.

Pressure, mm. Hg	Boiling-point, degrees	Pressure, mm. Hg	Boiling-point, degrees
47	22.1	290	57.1
51	24.5	346	62.1
60	26.2	360	63.4
90	31.7	425	68.5
110	35.6	500	72.7
125	38.5	580	77.2
203	49.0	675	82.5
250	53.5		

The boiling-points of aqueous mixtures of nitric acid at 760 mm., 360 mm., 250 mm., and 110 mm. pressure, and their composition, are given in Table II. Isobaric curves showing the change in the boiling-point with variation in the composition of the mixture are shown in Fig. 2. It will be seen that the curves are fairly parallel and that their shape is characteristic of a mixture of maximum boiling-point. From the data contained in Tables I and II, curves showing the change in vapor pressure with change in temperature have been constructed for a number of different aqueous mixtures of nitric acid. These curves are shown in Fig. 3. The percentages in this figure refer to nitric acid.

TABLE II.

Pressure = 760 mm.		Pressure = 360 mm.		Pressure = 250 mm.		Pressure = 110 mm.	
Per cent. HNO_3	Boiling-point, degrees	Per cent. HNO_3	Boiling-point, degrees	Per cent. HNO_3	Boiling-point, degrees	Per cent. HNO_3	Boiling-point, degrees
19.37	103.56	20.30	84.7	19.51	74.5	23.61	57.5
30.43	108.08	32.05	87.2	30.02	76.6	34.54	60.7
41.38	112.59	42.75	91.1	45.42	82.1	40.44	63.6
51.63	116.85	53.14	95.4	56.91	86.4	51.74	68.3
56.01	118.88	54.67	95.8	65.34	89.4	54.42	69.4
59.77	120.06	57.72	97.2	67.91	89.9	60.21	71.6
63.89	121.27	61.26	98.7	68.72	89.9	66.78	74.3
65.17	121.66	67.25	100.0	71.24	89.6	68.32	73.9
67.74	121.67	68.46	99.8	79.50	83.1	68.53	73.6
68.18	121.79	68.91	99.9	87.93	70.4	69.42	73.8
69.24	121.80	69.61	99.9	90.04	69.5	73.12	73.1
71.10	121.60	74.39	99.6	95.76	59.1	80.61	66.8
73.56	120.75	76.92	97.4	99.79	53.5	87.62	56.5
80.50	115.45	80.21	94.0			94.31	45.0
85.51	108.12	84.41	89.1			99.79	35.6
90.06	102.03	91.31	79.5				
95.45	95.42	99.79	63.4				

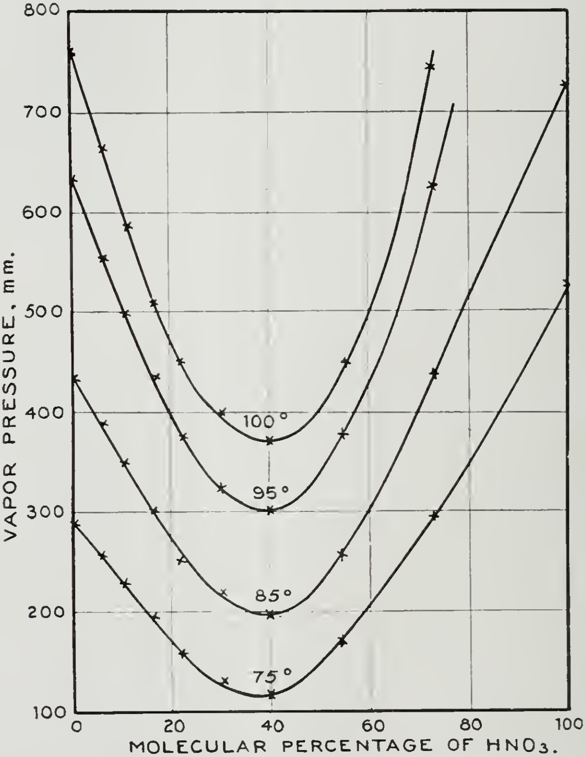
In Table III is given, for several temperatures, the change in the vapor pressures of aqueous solutions of nitric acid with the variation of the molecular percentage of nitric acid (number of moles of nitric acid per 100 moles of mixture) in the solutions. These isothermal changes are shown graphically in Fig. 4. The shapes of the curves in this figure are characteristic of mixtures of minimum vapor pressure.

TABLE III.

Per cent. HNO_3 by weight	Molecular percentage of HNO_3	Vapor pressure at			
		75°	85°	95°	100°
		mm. Hg	*mm. Hg*	*mm. Hg*	*mm. Hg*
0	0	289	434	634	760
20	6.7	260	390	554	663
30	11.0	230	350	497	585
40	16.8	195	300	435	510
50	22.0	155	250	375	450
60	30.2	135	225	330	405
70	40.1	115	195	300	370
80	53.5	170	250	375	450
90	72.6	295	440	625	745
100	100	524	725	. . .	. . .

As is to be expected with mixtures of maximum boiling-point, it has been found, on examining the curves given in Fig. 3, that the square root of the product of the vapor pressures of water and pure nitric acid, for any given temperature, is always greater than the vapor pressure of any mixture of nitric acid and water at that temperature. It is evident, from the position of the maxima of these curves, that the composition of the mixtures of maximum boiling-point formed by nitric acid and water changes but slightly with pressure. In order to confirm this, a number of determinations of the boiling-point and composition of the mixture of maximum boiling-point of nitric acid and water were made at 760, 360, and 110 mm. pressure. The results obtained are recorded in Table IV. In all determinations, 500 c.c. of the aqueous solu-

Fig. 4.



tion of nitric acid were placed in the distilling flask, the mixture then distilled until the temperature became constant, and distillation continued until only 15 to 20 c.c. of the liquid remained in the flask. The nitric acid content of this residual mixture was then determined by analysis with standard barium hydroxide. The mean values for the composition of the mixtures of maximum boiling-point in the following table are in good agreement with those previously determined by Roscoe.[5]

TABLE IV.

Composition of mixture before distillation, HNO_3	Mixture of maximum boiling-point at:					
	Pressure = 760 mm.		Pressure = 360 mm.		Pressure = 110 mm.	
	Composition, HNO_3	Boiling-point, degrees	Composition, HNO_3	Boiling-point, degrees	Composition, HNO_3	Boiling-point, degrees
60	67.90	121.80	66.95	99.8	66.73	74.2
65	68.28	121.57	67.20	99.7	66.77	74.2
67	67.96	121.59	67.15	99.7	66.81	74.1
68	68.17	121.58	67.08	100.1	66.78	74.3
69	68.24	121.67	67.16	99.9	66.82	74.1
70	68.18	121.79	67.24	100.1	66.85	73.9
71	68.35	121.85	67.18	100.0	66.87	74.3
80	68.36	121.76	67.25	100.0	66.79	74.4
Mean:	66.18	121.70	67.15	99.9	66.80	74.2

In conclusion, we wish to mention that experiments are now in progress, in this laboratory, on the determination of the vapor pressure of aqueous solutions of nitric acid at high pressures.

Chemical Laboratory,
Swarthmore College,
Swarthmore, Pa.

Electrolytic Iron. ANON. (*Sci. Amer.*, cxi, No. 2, 23.)—Considerable time has been required to make electrolytic iron available for industrial use, because it contained much hydrogen, due to the action of the current in the process. This makes it brittle and unsuitable for practical work, so inventors have been trying to get rid of the hydrogen and make metal of the usual quality. At the coming Lyons Exhibition samples of the new iron are to be presented in the shape of seamless iron pipe, which possesses great tenacity and ductility.

---

[5] Roscoe, H. E., *loc. cit.*

Production of Petroleum in Canada in 1913. ANON. (*Oil, Paint and Drug Reporter,* Aug. 31, 1913.)—The Department of Mines reports that the total output of petroleum in 1913 was 228,080 barrels, or 7,982,798 gallons, on which a bounty of $119,741.97 was paid. The total value of the production, at the average price for the year, $1.782 per barrel, was $406,439. The total imports of petroleum oil, crude and refined, in 1913 were 222,779,293 gallons, valued at $13,230,429, in addition to 1,628,387 pounds of wax and candles, valued at $108,897. The oil imports included crude oil 162,062,201 gallons, refined and illuminating oils 19,393,827 gallons, gasoline 29,525,170 gallons, lubricating oils 6,789,451 gallons. There was an increased importation in 1913 of all classes of oil with the exception of gasoline, the increases being most pronounced in crude oil and refined illuminating oil. There was comparatively little change in the production of natural gas in Ontario, but a large increase in the production in New Brunswick and Alberta. The total production in 1913 was approximately 20,345,000,000 feet, valued at $3,338,314, of which 828,000,000 feet were from New Brunswick, 12,487,000,000 feet from Ontario, and 7,030,000,000 feet from Alberta.

Ceresin Wax. E. J. PARRY. (*Chem. and Drug.*, lxxxv, 376.)—Paraffin waxes of different kinds have recently been adulterated with large quantities of rosin. The samples were sticky, showed uncertain melting-points, and tasted of rosin. They gave the color reactions for rosin, and had high acid and iodine values. Four samples gave: Acid value, 48 to 60; saponification value, 51 to 72.5; and iodine value, 40 to 56.

"New" or "Double" Gas for Small Plants. C. B. TULLY. (*J. Gas Lighting*, cxxvii, 452.)—"Double" gas is a mixture of coal gas and water gas, having a calorific power from 380 to 400 B.T.U., made by the gasification of coal and the generation of water gas from the resulting coke in the same plant. The gas can be made in small gas-works (5,000,000 cubic feet per annum) and sold more profitably at 2s. 6d. (60 cents) per 1000 cubic feet than coal gas (550 B.T.U.) at 6s. 3d. ($1.50). It is suitable for heating, and can compete with suction producer gas for gas engines. The plant consists of two gas-producers connected at the lower part, each surmounted by a vertical retort chamber surrounded by chequer-brickwork. The producers are "blown" to incandescence for about one minute by an up-draught, and the hot gases burned with a secondary air supply in the chequer-brickwork around the retorts, coal gas passing from the retorts to the scrubber during this period. Steam is then passed downwards through the hot chequer-brickwork of one producer, then through the two producer chambers in series, and upwards through the second retort chamber. During the next gas-making period the direction of flow is reversed.

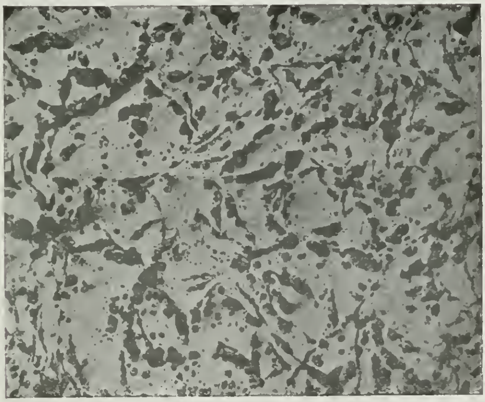
RECENT DEVELOPMENTS IN CAST-IRON MANUFACTURE.*

BY

J. E. JOHNSON, JR.,
Consulting Engineer and Metallurgist, New York, N. Y.

Third, oxygen seems to act as a brake on the separation of the carbon and to prevent the hard and strong needles of cementite which exist above the last transformation point from breaking down into graphite and ferrite, of which only the latter has any strength at all, and that much less than any other iron-carbon compound. This action is clearly shown in Fig. 28, a photomicrograph of a coke iron of excellent reputation, exhibiting a number of long, slender plates of graphite with similarly shaped bodies of ferrite on one or both sides of them. These jointly constitute the remains of crystals of cementite by whose breaking down they were formed. The structure is obviously a weak one, not only on account of its shape, but because the graphite

FIG. 20.



Unetched.

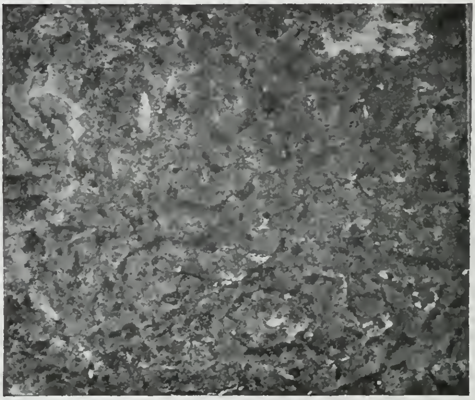
---

* Presented at a joint meeting of the Philadelphia Section of the American Society of Mechanical Engineers and the Mining and Metallurgical Section of the Institute held Thursday, October 8, 1914.

Continued from page 93, January issue.

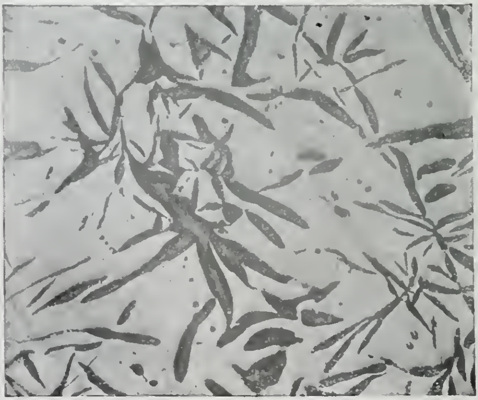
and ferrite are so much weaker than the original cementite. This structure is never seen in irons containing any important amount of oxygen, for the reason that oxygen seems to prevent the breaking down of iron-carbon compounds to a point very far below the pearlitic ratios of 0.9 per cent., such irons of moderate silicon ranging from 0.6 to 1.0 per cent. combined carbon and seldom containing any visible ferrite. I do not pretend to be able to explain this latter fact, but it is a fact in my own experience, nevertheless. The carbon range given, 0.6 per cent. to 0.9 per cent., is that embracing

Fig. 21.



Etched. (Magnified 100 diameters.) Good iron. Silicon, 0.70; oxygen, 0.065 per cent. Breaking strength, 1.25-inch bar, 3500 pounds, 4200 pounds.

Fig. 22.

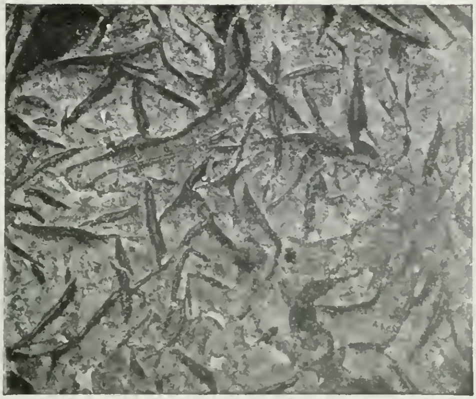


Unetched.

the strongest steels, and this fact is undoubtedly of considerable influence in making these irons so strong.

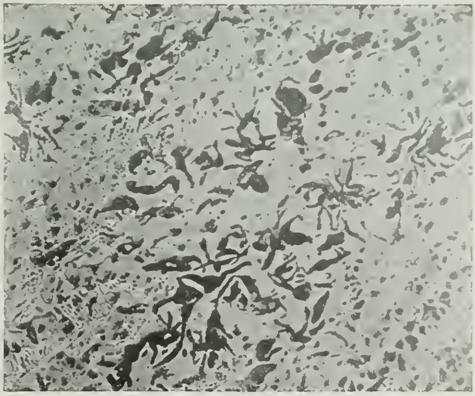
Fourth, oxygen has an effect on a matrix itself, considered as a steel. This, as is known by the best-informed steel metallurgists, is that it strengthens the steel, but reduces its elongation and increases its brittleness. Undoubtedly the oxygen exercises the same influence on the matrix of the iron, but the results as regards brittleness are the opposite of what they are in steel, because nothing promotes brittleness so much as gashes in the

FIG. 23.



Etched. (Magnified 100 diameters.) Poor iron. Silicon, 0.72; oxygen, 0.009 per cent. Breaking strength, 1.25-inch bar, 2500 pounds, 2500 pounds.

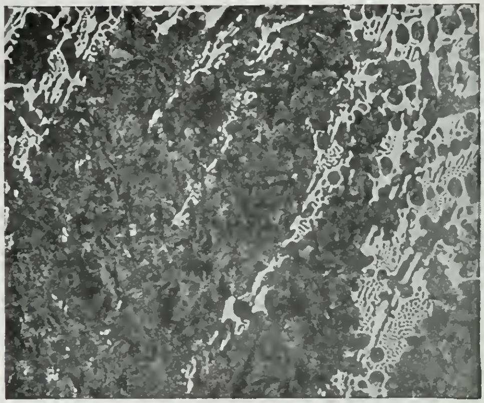
FIG. 24.



Unetched.

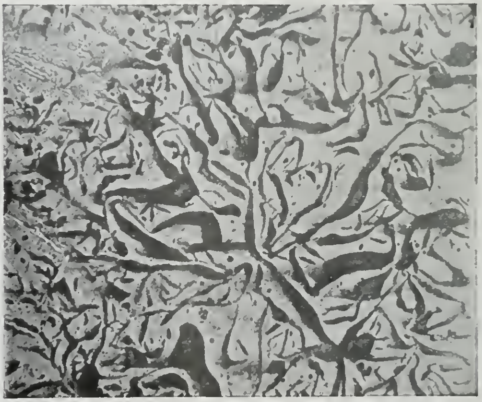
material, such as are caused by flat flakes of graphite, and suppressing these not only increases the strength, but also largely eliminates what might be called incipient cracks, from which breakage might start; and this effect, therefore, reduces the brittleness of the metal far more than the slight effect on the matrix increases it. As a matter of fact, soft irons containing oxygen have not only greater strength, but also a degree of toughness amazing to those used to only ordinary cast iron; they seem almost to bend before breaking.

Fig. 25.



Etched. (Magnified 100 diameters.) Remelt. Silicon, 0.70 per cent. Breaking strength, 1.25-inch bar, 4150 pounds.

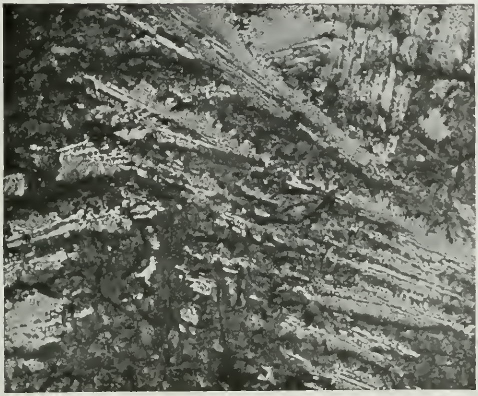
Fig. 26.



Unetched.

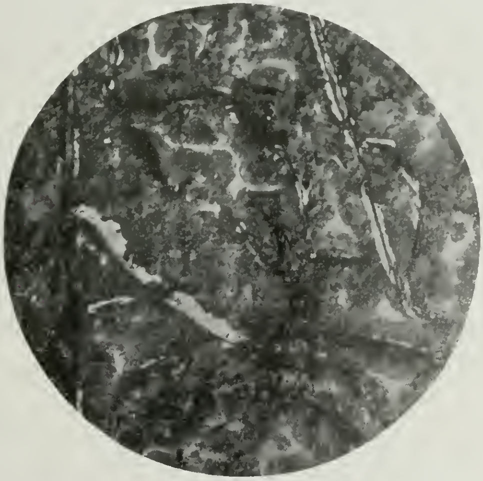
Fifth, oxygen exercises also a very important influence on the chilling power of the iron, due to its retardant action in the separation of the carbon, and it was undoubtedly for this reason that the use of high-grade charcoal iron was formerly almost universal for car wheels and remains accepted practice to-day for the production of those chilled castings which demand high quality and bring a high price. It seems to be a fact that the presence of oxygen not

FIG. 27.



Etched. (Magnified 100 diameters.) Remelt. Silicon, 0.72 per cent. Breaking strength, 1.25-inch bar, 2750 pounds.

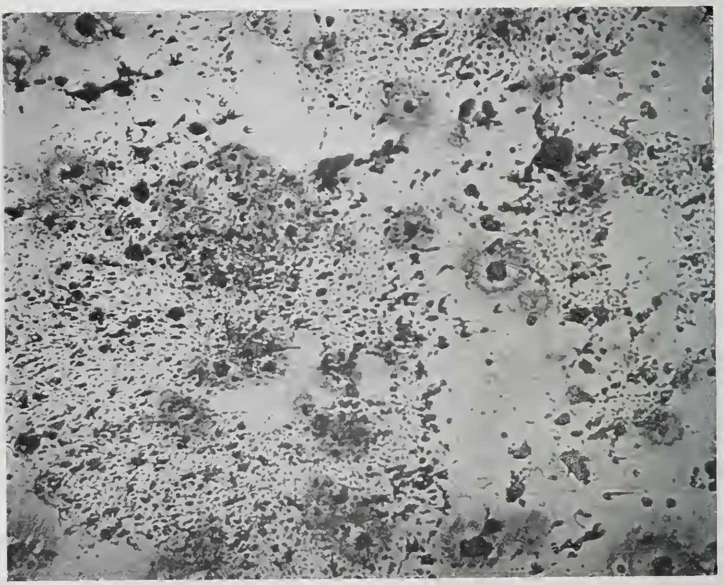
FIG. 28.



Etched. (Magnified 70 diameters.) Coke iron. Note the long, slender bodies of graphite and ferrite side by side, formed by the breaking down of cementite crystals.

only increases the chilling power of the iron, but also increases its sensitiveness to chilling influences. An iron containing oxygen, if cast in sand, will retain somewhat more combined carbon than a similar iron not containing oxygen cast under the same conditions, and if the irons are cast against a chilling surface the one containing oxygen will begin to show a white chill at a higher silicon than the other, and will continue to show greater chill for the same silicon as the latter element decreases all the way to the lowest limits. Moreover, the character of the two chills is quite different. The chill of the oxygen-free iron is made up of needle-shaped crystals, or rather crystals shaped like long, slender pyramids, with their axes perpendicular to the chilling surface, their sides brilliantly polished, and making sharp angles with each other, so that the crystalline mass has but little strength in any direction parallel to the chilling surface. The chill of the oxygenated iron, on the other hand, shows crystallization normal to the surface. But these crystals, instead of being highly polished,

Fig. 29.



Unetched. (Magnified 100 diameters.) "Special" charcoal iron, showing finely-divided and almost completely nodular graphite.

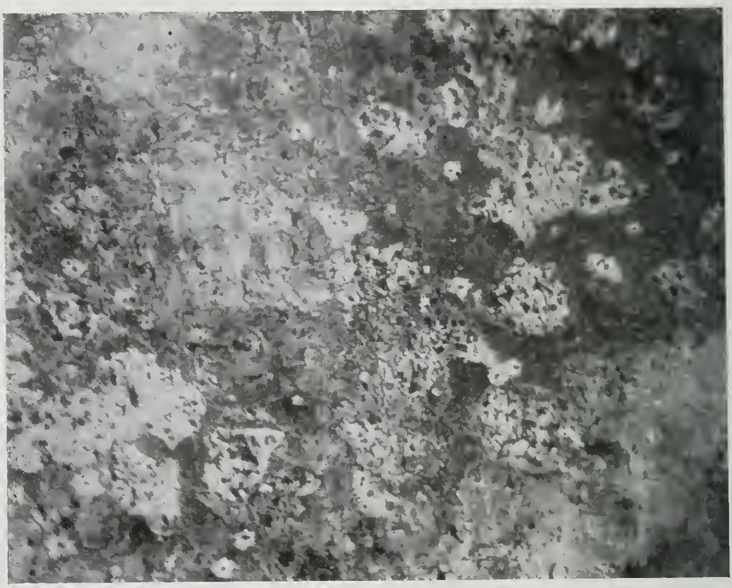
have rough faces, so that they interlock with one another. The chill shades well into the gray at the base, the mottled area containing little stars of graphite in the field of white. It is impossible to describe in detail, or even to show by photomicrographs, comparative chill structures, but those whose business is the manufacture of high-grade chilled castings have never ceased to use charcoal irons, even though they cost two to three times as much as coke iron of the same nominal analysis, for the reason that, with this iron, they have found by experience they can produce castings of a quality to justify their customers in paying the difference in price.

That the difference between charcoal iron and coke is in the carbon and oxygen I have described already, and in those two elements alone we have proved (so far as anything is capable of any absolute proof in so complicated a subject) by analyzing not only for all the common elements, but also the rarer ones and for gases such as nitrogen and hydrogen. Hydrogen we found to be absent, but nitrogen we found to be present in varying quantities, but no variation of the quality of the iron attributable to its variation could be observed, and, while we added nitrogen to the remelts by introducing nitrogenous substances, the differences produced even by considerable additions of nitrogen were unimportant.

Here, then, we find, as has so often been found before, that these curious, one might almost say mysterious, variations of quality arise not from variations of one element, but from simultaneous variations of two. We have variations of carbon from well above to well below the eutectic ratio, with the resulting low quality in the first case; and we have, with this, variations in the oxygen whose presence results in greatly improved quality, whether with high or with low carbon. Considering the complexities of the operation of the blast furnace, the little that we have known until recently about its thermal equilibrium and the variations in the latter produced by different conditions of working, and the effect of these variations on the carbon and oxygen contents of the iron produced, it is not surprising that the variations in the quality of charcoal iron, as controlled by variations of furnace practice, were so difficult of understanding as to seem positively mysterious.

The analysis of the thermal equilibrium of furnaces, to which I have before alluded, shows that those furnaces which produce good iron run with a relative deficiency of heat in the hearth, while those which produce bad iron run with an excess of heat in the hearth. Observation both by eye and with the pyrometer shows that irons made under the latter condition are much higher in temperature as they come from the furnace than those made under the former, and this leads to two results—elimination of oxygen (which appears to be a function of temperature more than anything else) and super-carbonization of the iron, because while we know but little concerning the conditions which control the carbonization of iron, we do know that the degree of saturation possible increases with the temperature. We find, therefore, that those furnaces which work with excess of heat in the hearth tend to super-carbonization and to complete deoxidization, thereby lowering the quality of the iron, both by giving the weak eutectic structure to the matrix and by cutting it to pieces with large flakes of graphite.

Fig. 30.



Etched. (Magnified 100 diameters.) Same as Fig. 29.

In the case of cold blast charcoal iron, we have probably a modified condition of the enormous volume of carbon in the hearth tending to carbonize this iron more highly than normal, in spite of its low hearth temperature. We have here, then, a condition tending toward fairly high carbon, but also a condition of low temperature favoring high oxygen, and these are characteristic of iron produced by this process. The carbons are not excessive, ranging around 4 per cent. in good, cold blast iron, while the oxygen is the highest in any standard variety of iron produced, ranging in such samples as we have analyzed from about 0.05 to 0.07. These two facts are largely responsible for giving this iron its desirable characteristics, because the presence of oxygen seems to prevent absolutely the excessive graphitization of carbon, even when the carbon contents are high. This seems to be in line with the fact above mentioned, that oxygen exerts a general tendency in the direction of preventing the breaking down of the combined carbon into the graphite form.

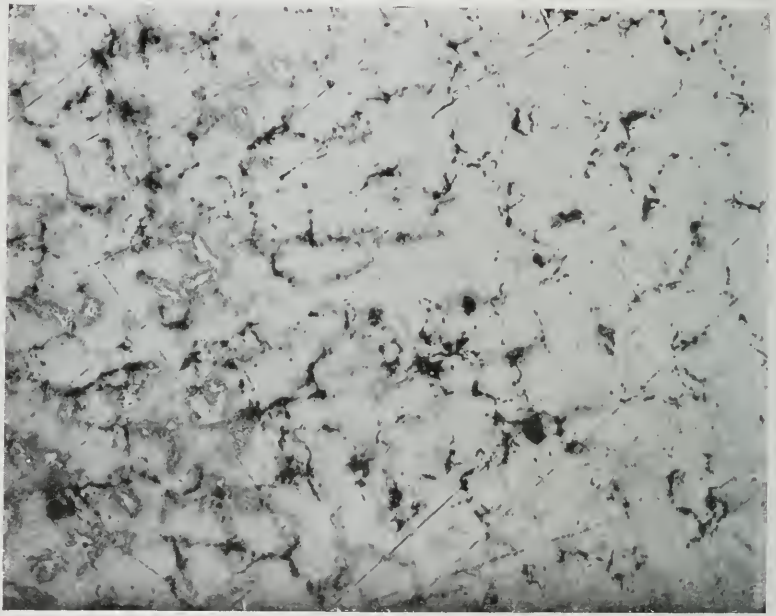
Thus, with cold blast iron, we can secure the benefit of a large percentage of cementite in our chilled castings, without the danger of having this break down into graphite, as happens with carbon irons free from oxygen. We are able, therefore, to obtain extremely hard chill along with the extreme closeness of grain and the accompanying physical strength in the gray portion which oxygen brings.

MANGANESE.

Manganese has been praised by many as a panacea for almost all the ills to which the foundry trade is liable, whether from too soft or too hard castings. On the other hand, it has been unhesitatingly condemned by many other able foundrymen as the basis of most of our errors in foundry practice, particularly in the line of chilled castings.

The effect of manganese on steel has been exhaustively investigated (see "Manganese Steel," R. A. Hadfield, *Journal Iron and Steel Institute*, 1888, vol. ii), but, within the limits in which it is used in foundry practice, it is probable that we can largely ignore this effect on the matrix of the iron, on account of its more important collateral actions. These are important, and are two or three in number, and it is certain that the effect of manganese, like that of silicon, undergoes a reversal after it exceeds a certain amount. Manganese has a greater affinity for sulphur than has iron. It is, in fact, a much more active element chemically than iron in all particulars. As a result, it takes the sulphur away from the iron and forms with it manganese sulphide. It is a general law of metallurgy that a metal will dissolve compounds of itself, but not compounds of another metal with anything like the same facility. In consequence of this law, the manganese sulphide separates out from the iron and rises to the surface. It may be seen doing this in the ladle under certain conditions, and even where it does not separate out completely, manganese sulphide, not being dissolved by iron, is much less harmful than iron sulphide, which is dissolved by it with the consequences above described.

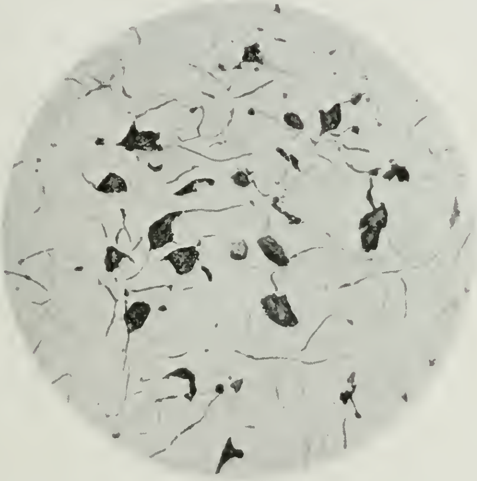
Fig. 31.



Unetched. (Magnified 100 diameters.) Coke iron-oxygen, same as Fig. 6. (Kindness of Professor Campbell.)

The first effect of the addition of manganese is, therefore, to remove a part of the sulphur. The action is not quantitative, and several times the amount of manganese sufficient to form manganese sulphide with all the sulphur present must be added to obtain the removal of much of this latter. The manganese which does not combine with the sulphur combines with the iron, when molten, in the condition of a double carbide. Manganese, having a higher affinity for carbon than iron, causes an increased absorption of carbon by the metal in the blast furnace, even up to 6 or 7 per cent. in ferro-manganese and up to 4 or 5 per cent. in spiegeleisen containing 18 to 22 per cent. of manganese. The effect of the manganese itself, after it passes 1 or 2 per cent., is to harden the iron, by holding more of the carbon in the combined condition. This increases the strength of the matrix in ordinary gray irons and also limits the formation of graphite. The result of these actions is that manganese strengthens the iron in addition to increasing its chilling power, and it is used for this latter purpose to make chilling irons harder, as well as to make soft irons softer. It is obvious, from what has been said, that these actions are the results of two different sets of effects, one of which predominates in the one portion of the manganese range and the other in the other. The objection to the use of manganese for producing chill is that iron containing much of it crystallizes into large, knife-like crystals with extremely smooth faces, so that the end of a broken pig of spiegel often shows crystals sticking out almost like knife blades, and the whole surface is made up of the faces of intersecting crystals with but little cohesion with one another. It is

FIG. 32.

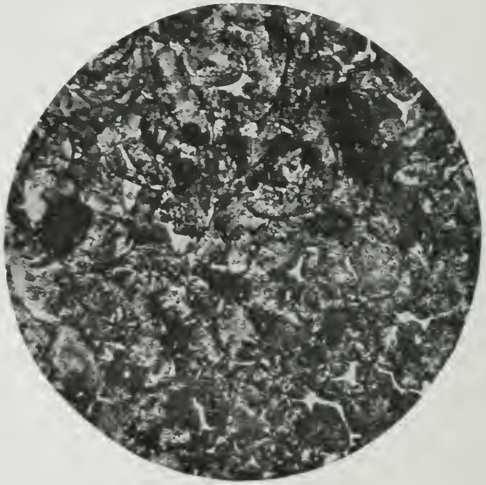


Unetched. (Magnified 100 diameters.) Oxygenated coke iron, showing nodular condition of graphite.

probably this tendency which gives car wheels, which obtain their chill by the use of manganese, their tendency to "shell out," that is to say, under extra stress, a group of these crystals lose their cohesion with one another, loosen and finally fall out, producing what car-wheel men call a "shell-out." Moreover, the manganese chill is much softer than a straight iron chill, and breaks down under wear.

The activity of manganese as a deoxidizer, as well as a desulphurizer, is well known, and when manganese is added to metal high in oxygen some of this latter oxygen is promptly scoured out; the chilling power and strength of the metal are thereby reduced. On the other hand, if still more manganese be added, when 1½ to 2 per cent. is reached, the strength of the iron and its chilling power increase, on account of the direct action of the manganese in throwing the carbon into the combined condition, but in the form of flat plates, as I have just explained. This conflicting tendency, in conjunction with its effect in removing sulphur and the powerful effect of that element on the quality of the castings, makes it perfectly evident that the rôle of manganese is an extremely complicated one, but, on account of this powerful deoxidizing influence, it is my judgment that it should be kept low in all castings where the highest qualities, particularly strength,

Fig. 33.



Etched. (Magnified 100 diameters.) Same as Fig. 30.

closeness of grain, and chilling power, are desired, because while these qualities *of a kind* can be obtained by the use of manganese in considerable quantity, the fundamental structure of the iron produced is inherently inferior to the structure produced by the presence of oxygen, and it is a matter of established practice that, in the production of chilled castings, the desired result cannot be obtained by the addition of ferro-manganese alone, as at one time was thought to be the case.

Some manganese, perhaps up to 0.5 or 0.6 per cent., is desirable in cupola melted iron, to hold the sulphur in check, and it may be useful for other purposes in special cases, but for the best castings manganese should generally be kept within very moderate limits. Some of the manufacturers of chilled rolls will not tolerate it above 0.30 per cent.

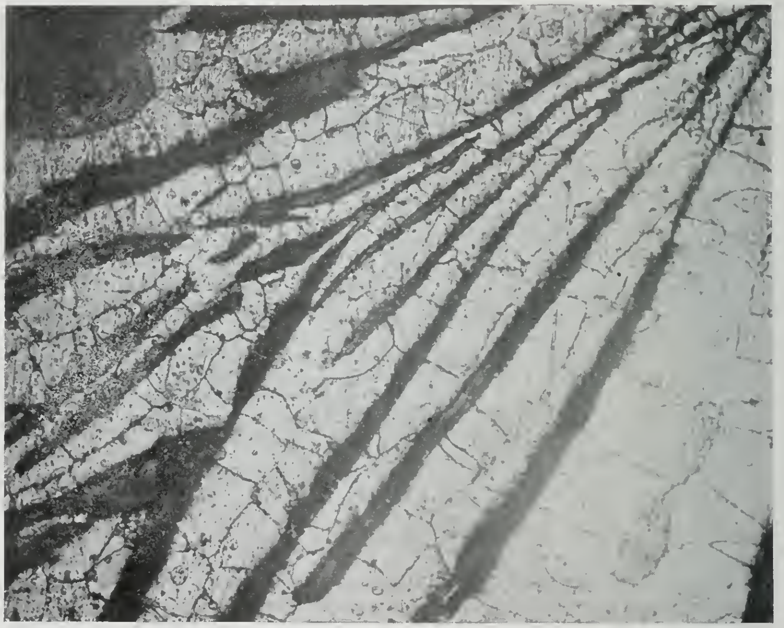
THE EFFECTS OF TIME.

Before discussing the effect of other elements on the iron-carbon alloys, it might be well to discuss the effects of time. The iron-carbon diagram shows only equilibrium conditions, and the time required for the attainment of some of the equilibriæ shown by the iron-carbon diagram is extremely short, while for others it is very long. Hence the diagram cannot tell us what will happen in any actual case unless the time factor is considered.

The most important effect of time (that is, of the rate of cooling) is its influence on the graphitization of the carbon after solidification. The evolution of graphite during cooling through the molten condition seems to occur only with hypereutectic irons, and this appears to be a function of time, because irons which throw off graphite into the air as they run from the furnace can only be converted into good castings from this initial heat by pouring hot and just as quickly as possible. If poured slowly, the graphite will accumulate at the top of the mould so as to make the whole top of the casting worthless—it will be "worm eaten" at the best, and at the worst may contain great cavities filled with loose graphite flakes of large size. Whether hot pouring simply causes the metal to set more quickly and thus prevent the rising of the hypereutectic graphite, or whether the formation of the graphite is actually prevented, I have never determined, but it is probable that both effects play a part.

In regard to the graphitization after solidification, our knowledge is more definite. In this case all the carbon not thrown out as hypereutectic graphite is combined at solidification, and, if the cooling be rapid from that point, the iron will remain perfectly white. But, if the casting be made to cool slowly, it will not only graphitize, but the graphite may form into very large flakes. The best illustration of this is to be found in the salamander taken from the hearth of the furnace after blowing out. This contains huge flakes of graphite an inch or two in extent, and the intersections of the flakes cut the iron into irregular solids quite without cohesion, so that a large lump of salamander can frequently be broken apart with the fingers into pieces of small size, each consisting solely of iron and graphite. Fig. 34 shows a microphotograph of such a piece, and shows why this must be so. The iron in this case has remained just below the melting-point for several years.

Fig. 34.



Etched. (Magnified 100 diameters.) Salamander. The heavy bands of graphite have completely destroyed the continuity of the structure.

From this point of view, the action of chilling becomes extremely simple. We merely shorten the time of cooling through the range in which graphitization could take place so as to prevent or diminish this action and leave the carbon in the combined condition. The surface next the "chiller" is the whitest and hardest, because its heat is removed instantly, while the metal back of it has to be conducted through the chilled surface and also through the warmed face of the chiller into the cold metal behind it. This is obviously a much slower operation, and, as a result, more graphitization can occur in the metal behind the chilling face.

In the same way, if the chiller be too light in proportion to the body of the metal to be chilled, a very insufficient chill will result, because the thermal capacity of the chiller is only sufficient to absorb the heat from a thin zone of the molten metal, and this is promptly heated up again by the larger body of molten metal behind, which "draws" the chill already formed, exactly as a blacksmith draws the temper of the quenched edge of a tool.

Silicon and time, then, are seen to be the principal factors making for graphitization, while oxygen, sulphur, and manganese are the principal ones resisting it. Of these three, manganese is hostile to the other two, and, if present in sufficient quantity, destroys their effect, while its own effect does not alone give a chill of the character desired. Sulphur gives a hard chill, but an essentially brittle and unreliable one, accompanied by high shrinkage and weak structure back of the chill. Oxygen gives a tough, hard chill, low shrinkage, and the strongest and best structure back of the chill.

THE LESS COMMON ALLOYING ELEMENTS.

Chromium.

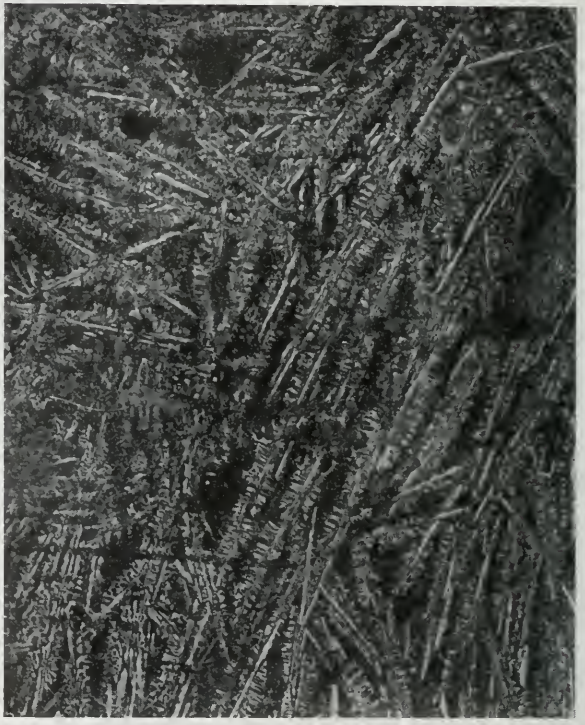
The effect of chromium on iron and iron-carbon compounds has also been extensively investigated by Sir Robert Hadfield.[2] The effect of chromium is to harden the matrix of the iron, making an intensely hard but very brittle double carbide of chromium and iron. In low carbon alloys this makes a very strong, hard steel of low elongation. When the metal contains enough carbon to constitute cast iron, the tendency is to throw more and more of it into the combined condition, until, at 3.0 or 4.0 per cent. chromium, the metal is entirely white, the fracture being flat, shining, highly polished plates, very similar to those in spiegel, and to those of weak iron carbon eutectic previously illustrated. (Compare Fig. 35, showing chromiferous iron, with Figs. 3 and 4, showing weak, high carbon, spotted iron.)

---

[2] *Journal of the Iron and Steel Institute,* 1892, vol. ii.

There is no doubt that chromium strengthens iron by throwing the carbon into the combined condition and by closing up its grain. It enables a hard chill to be secured, even in spite of the influence of a considerable percentage of silicon; but the structure consisting of these laminated plates has not the staying power of a chill produced by oxygen content without any other substance.

FIG. 35.



Etched. (Magnified 100 diameters.) Chromiferous pig iron. Note similarity to eutectic structure of (mesh) spotted iron, Figs. 3 and 4.

Fig. 36 shows a strong charcoal iron remelted in a crucible with sufficient chromium to raise the content of the remelt to 4 per cent. The structure to which I have alluded is strikingly shown. Test bars made from this mixture were strong, but not by 20 per cent. as strong as test bars made from high oxygen iron without such a mixture. Chromiferous iron, particularly a natural alloy made from certain ores, which contain chromium and nickel to the extent of about 2.5 and 1.25 per cent. respectively, has been urged, in the past, as a substitute for the best grades of charcoal iron. It has only been moderately successful, however, in meeting the claims made for it. It would seem that it is impossible for this alloy to equal the product which I shall presently describe, since this product is far superior in quality to charcoal iron.

Nickel.

Nickel seems to be one of the few metallic elements which produces a truly beneficial effect on the character of cast iron. Its highly beneficial effect on steel has long been understood, but this effect does not begin until the amount of nickel exceeds 3.0 per cent. Beneficial results are derived by its presence in cast iron to the extent of only 1.0 or 2.0 per cent. It strengthens the iron and improves its chilling power, without appearing to cause any lamination or other objectionable features. These statements are based solely upon some experience made at Ashland by remelting irons in the crucible with nickel sufficient to give the above-mentioned percentages, and it would be unwise to generalize too widely on such limited data.

It is, of course, not to be overlooked that the expense of nickel for treating cast iron is almost prohibitive. One per cent., or 22 pounds, would increase the cost about $7 per ton, and that consideration, taken in conjunction with the fact that even nickel is not able to produce results as good as those obtainable with the new kind of iron presently to be described, makes this an unprofitable field for further research.

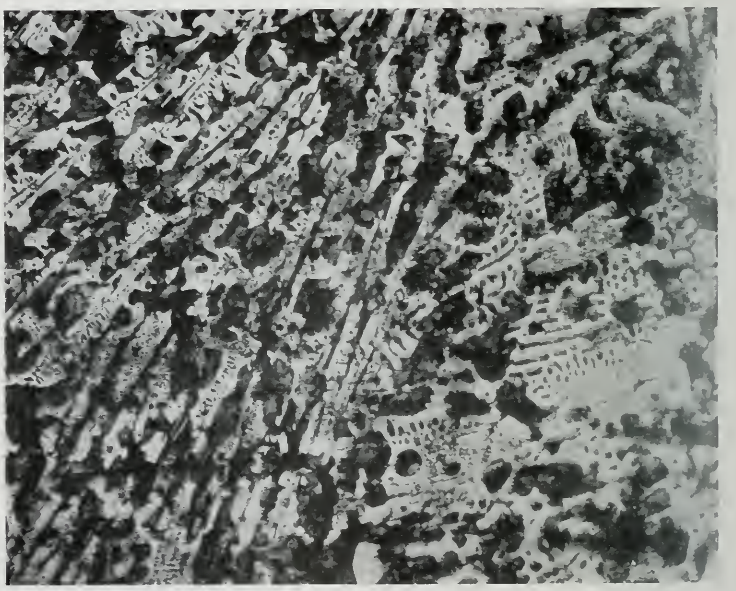
For strong, tough irons with hard, wear-resisting chill no material has apparently been developed as good as an iron containing as much oxygen as its silicon content will permit.

Titanium.

The effect of titanium on cast iron is a much-discussed question, and not nearly so much experience is available for the solution of it as in the case of manganese, but the probabilities are that the action of this alloy has also very contradictory effects, on account of its action on different elements.

An extensive paper on the subject was published by Professor Bradley Stoughton before the American Institute of Mining Engineers in 1912, but the results recorded as to the effect of strength of cast iron, etc., were rather contradictory. One thing, however, seemed to stand out very clearly, and this was that titanium reduced the chill. This is in accordance with what we should expect, for titanium is one of the strongest deoxidizers known. It also has a very high affinity for sulphur and nitrogen. Such effect as nitrogen has is undoubtedly in the direction of producing chill, and therefore, the effect of titanium would tend to remove three elements producing chill, namely, oxygen, sulphur, and nitrogen. This amply explains why the chill is reduced, and probably explains also why the results on strength are so contradictory. The titanium removes the highly beneficial oxygen, and it also helps to remove the detrimental sulphur.

FIG. 36.



Etched. (Magnified 100 diameters.) Pig iron with 4 per cent. chromium. Note flat crystals and compare with Figs. 3 and 4, "spotted" (poor) charcoal iron.

The reduction of chilling power which is admitted by advocates of the use of this alloy for cast iron requires the use of more manganese for its restoration, and this is highly objectionable, for reasons already pointed out, and it seems extremely doubtful that any benefit will be found by prolonged experience to result from the use of titanium in cast iron, even in spite of the fact that its action on the matrix of the iron itself may be to strengthen it. Its influence in removing oxygen in good castings is extremely detrimental, and this is probably not offset by any other beneficent action which it may have, while where particularly good castings are not required there is no call for the use of any treating material whatever.

Vanadium.

Following the general custom of claiming a beneficial action on cast iron for any alloying material which has been found useful in steel manufacture, traces of vanadium have been claimed to have a beneficial effect on cast iron. Vanadium, like titanium, is a powerful scavenger. Its best-informed advocates claim that its principal service is not in remaining in the steel itself, but in going out of it with the oxygen, nitrogen, etc., which it removes.

This is exactly the same effect as that produced by titanium, and it seems almost certain that vanadium will be found objectionable in good irons containing oxygen, as it has already been found to be without benefit for ordinary castings not containing that element.

Great claims have recently been made for irons containing traces of this element, but the photomicrographs used to illustrate the claims did not display a particularly meritorious structure, and the results of the physical tests given were so far below the results obtainable with irons containing oxygen as to be beneath comparison with them.

As a result of this review of all the metals that are claimed to benefit cast iron, we see that most of them, with the possible exception of manganese, have based their principal claims on being deoxidizers, although some also have merit as desulphurizers, and some have a direct effect in throwing the carbon into the combined condition.

We have already seen, and I trust that I shall be able to show still more clearly presently, that oxygen is of greater benefit to cast iron than any other element at our disposal, with the exception of silicon, and that any addition to the iron which tends to remove oxygen is not beneficial to it, but is highly objectionable, the accepted theories to the contrary notwithstanding.

We have seen, by unmistakable evidence also, that, while some of these metals tend to throw the carbon into the combined condition, the form into which they throw it (or rather the type of crystallization which they induce) is an extremely objectionable one, being inherently weak and brittle, and that the sole benefit which we can expect from the use of these metals is the removal of a portion of the sulphur, for which a small amount of manganese seems to suffice—at least to the extent to which such removal is possible. When this result is accomplished with manganese in moderation, the strength of the iron is not materially impaired, though its chilling power, in the judgment of some expert users, is decreased after the manganese increases above 0.3 per cent.

It seems safe to say, therefore, that, if it were not for sulphur, the more perfectly we dispensed with any of these alloying metals the better iron we should obtain where strength, close grain, and strong, hard chill are the qualities desired.

Remember now the demonstrated fact that the old-fashioned cold and warm blast charcoal iron contained much oxygen, and you will understand that the conscientious founder, in his insistence on the use of these materials for high-grade chilled castings, was not actuated by prejudice and ignorance, but by a profound knowledge of his subject, even though he could not explain the reason for the results produced.

It will be clearly recognized that this is a flat contradiction of the tenets of theoretical metallurgy, but we find it necesary in every science to recognize, from time to time, the fact that we have taken a wrong trail and are being led from, not toward, our goal, and the only thing to do under such circumstances is to leave that path and take up the correct course, even though we have to retrace our footsteps in doing so.

A critical examination of the basis of the old theory will disclose the fact that the amount of real evidence on which it rested was small. No work of any amount in determining the actual oxygen present in cast iron by the combustion method has ever come to my attention, except that which we initiated at Ashland, and, while some work has been done by solution of the iron and determining the residual oxide, this method cannot receive much consideration on account of the vast possibilities of oxidation during solution.

It is true that there is a vast amount of inferential evidence available to the careful observer that oxygen produces a difference. I was convinced that there was oxygen in some iron ten years before I had obtained any determinations of that element, and the results of the subsequent determinations have shown that I was right, but, because the iron produced was for steel-making purposes, and, when high in oxygen, was generally high in sulphur also (and therefore rejected by the steel works), I considered the effect of oxygen harmful. This was a coke iron, and when I first saw the " special " charcoal iron I condemned it as worthless, because of its strong resemblance to this high oxygen coke iron. The introduction of the testing machine soon showed the complete fallacy of this judgment.

On the other hand, much has been said as to the burning of iron by overheating it, and its poorer quality when overheated has been attributed to the introduction of oxygen, especially in air-furnace work. The explanation will work just as well if turned the other way around. When metal is overheated in the air furnace the oxygen, of which that apparatus introduces a little, reacts with the silicon or carbon, or both, and goes out, weakening the iron and impairing its quality, just as the exponents of the " burning " theory contend.

The fact that increasing temperature promotes the elimination of oxygen is proved by several facts. The " Experiments on the Overoxidation of Steel " carried on by Messrs. Shimer and Keachline, and reported by them in a paper before the American Institute of Mining Engineers, showed that, as the temperature went up, less oxygen stayed in. These investigators found less oxygen in steel with only about 1.0 per cent. carbon and no silicon than we find in cast iron with 3.5 per cent. carbon and 1 or 2 per cent. silicon, because the temperature of molten steel is some five hundred degrees higher than that of cast iron.

In the course of my own experience, I have seen a heat in a small converter purposely blown cold until the silicon was removed, but most of the carbon left in. This metal was alive with oxygen. It was exceedingly " wild " when hot, and when cold it was so full of blowholes as to have no strength whatever. The same iron, blown hot, yielded steel of a very high temperature, containing only about 0.06 per cent. carbon, and was absolutely quiet, even before the addition of the deoxidizers, and poured like cream.

All these facts agree with the well-established general law that the affinity of carbon for oxygen increases very rapidly with the temperature. You will see then that, while the view I am offering you is opposed by an accepted theory, it is supported by a vast array of established facts.

In spite of the volume of evidence which we have accumulated, and which I have set forth in the published paper above mentioned, I am well aware that it would be impossible for many to accept my conclusions on this evidence alone. I shall pass, therefore, to the second stage of my subject, namely:

THE PRODUCTION OF AN IRON HIGH IN OXYGEN AND THE CHARACTERISTICS OF SUCH AN IRON.

When I had obtained what seemed reasonably valid testimony that oxygen was the cause of the good qualities in charcoal iron, I began to experiment with methods of introducing it at will by different ways of operating the furnace, and also by introducing hot ore, mill scale, etc., into ladles and then filling the ladles with iron as it came from the furnace. This yielded no useful result.

After I had left the charcoal iron business I began to investigate further the conditions under which silicon and carbon were removed from iron during its conversion into steel, in order to obtain a method of introducing oxygen into iron at will without lowering the carbon. I found from the steel men that by starting with a very hot heat in the Bessemer, they could blow the carbon out to a very considerable extent before the silicon was gone, while with a comparatively cold initial heat the silicon would practically all disappear before the carbon began to be removed. Moreover, it seemed perfectly evident that the reason I had been unable to get oxygen into normal irons, either in or outside the furnace, was because, at the temperature at which I was working, the activity of the silicon and that of the carbon were such that they instantly removed the oxygen. It is, of course, no trouble to resiliconize a bath of metal, and therefore it seemed to me that if I could take metal and reduce it to the condition of the spongy white iron, which we obtained from the furnace when it was so cold as to be almost chilled, and could then mix that with normal iron high enough in silicon to give the resulting mixture the desired silicon contents (all the while keeping the temperature as low as possible), I should reproduce, outside the furnace, the conditions which had existed inside it, always providing that the temperature was kept low enough, because observation of converter practice had convinced me that 0.05 per cent. carbon was more efficacious in removing oxygen at 3000° than was 3 per cent. at 2300°. Accordingly, therefore, I had preliminary tests made at a steel-casting plant. A heat of metal of 1.0 per cent. silicon was blown in the side blow converter, holding the temperature down by stopping the blow and turning down the heat several times. The blow was continued until the carbon flame began to break through, showing that the silicon was gone and the carbon was beginning to go. The blow was then stopped and the vessel turned down. The sample of metal taken from it at that time was, when cold, a white iron full of blowholes, rotten, brittle, and worthless to the last degree. With this was then mixed an equal volume of 2.0 per cent. silicon iron direct from the cupola, and from that mixture test bars were cast. Test bars had also been cast of the original metal, both the 1.0 per cent. silicon iron and the 2.0 per cent., and these broke at approximately 2300 pounds on 1¼-inch round bars on 12-inch centres. Similar bars from the treated metal broke from 4000 to 4300 pounds.

Steps were then taken to obtain patents on this process, and you will well believe that, in view of the current opinions in metallurgy, there were but few citations from the Patent Office of anything of a similar nature. On the contrary, the patent examiners found my statements and claims so utterly at variance with all the accepted theories on the subject that they were inclined to consider me a victim of self-delusion. However, we had at hand a mass of evidence, and when it was presented to them they became convinced that, while there was a conflict between the accepted theories of metallurgy and the facts, it would be better to give precedence to the facts, and let the accepted theories go, and they allowed the patents in their broadest possible form.

After this a number of furnace companies were approached, with the view of having them undertake the manufacture of the new metal, and, unless one had experienced it, one would not believe with how little enthusiasm the proposal was received. Finally I went to Mr. E. A. S. Clarke, president of the Lackawanna Steel Company, and he asked me to go to Buffalo to see those in charge of the company's plant there, at the same time accompanying his invitation with intimations of the skepticism of all parties in regard to my process and the results claimed for it. When I reached Buffalo this skepticism was made even more evident and put in more direct language, but when I showed them the experimental results which I had obtained at the steel-casting plant they waived their doubts for the time being, and consented to make a trial of the process. At the first attempt, the conditions were not altogether favorable. A plant laid out for the production of steel, with no idea of ever desiring to oxygenate pig iron, may obviously not be ideally arranged for the latter purpose, while blowers, familiar with the necessity of getting a high temperature to produce good steel, found it difficult to blow a heat as cold as possible. Moreover, the iron which was used to mix with the blown metal was lower in silicon than we had expected to get, and this resulted practically in a " mottled " iron. All these conditions militated against the success of the trial. Nevertheless, test bars, made from the metal after treatment, showed an increase of about 20 per cent. in strength over the original iron even after remelting, and the Lackawanna Company then felt justified in making another test and arranging the conditions more in accordance with the requirements of the operation. At this second test we provided a metal of about 2.5 per cent silicon to mix with the blown metal. The phosphorus was also increased so as to give a result comparable to foundry iron. The metal to be blown was taken from the mixer, and was mixed half-and-half with the high silicon metal, and test bars 1¼-inches round and 2-inches square were cast from the mixture to determine the strength of the iron before treatment. After the converterful of mixer metal was blown the high silicon iron was added, and additional test bars were made from this mixture. The 1¼-inch round test bars of the original untreated metal broke at about 3100 pounds average; high silicon metal, and test bars 1¼ inches round and 2 inches centres. Of the treated metal, the 1¼-inch test bars broke at about 5100 pounds average, and the 2-inch square test bars broke at 22,900 pounds average. The 1¼-inch test bars were a little over size in each case, but about the same amount in each, so that the results are comparable. By a curious coincidence, the increase in strength, based on the average of all the good bars, worked out to exactly 70 per cent. in both cases. Since that time other heats of other silicon have been made, and the strength is in all cases well above 20,000 pounds on the 2-inch square bar.

The first questions you will naturally ask are: Does the oxygen stay in this iron on remelting, and, if so, why? Why do not the carbon and silicon which are present scour it out, and restore the iron to its normal condition?

The answer to the first is the important one from the commercial point of view, and so soon as we have obtained these results we put some of the iron produced through a cupola as a separate charge. When it came out we raised the silicon with ferro-silicon from 1.26 to about 1.50 per cent. so as to make it comparable with ordinary iron from the cupola. Even after this treatment with ferro-silicon, which tended to deoxidize it and also to throw out the carbon into the graphitic condition, the strength remained at 21,000 pounds. We had previously demonstrated, by an extensive series of remelts of charcoal iron in crucibles, as described in the paper above mentioned, that the oxygen did remain, and that, as I have already stated, an iron which went into the crucible strong came out of it strong. The actual presence of the oxygen after remelting, as well as before, was determined by analysis before and after the results.

The reply to the second question seems at first sight more difficult, but it is not really so. It seems to be a perfectly general law of chemical action that, while reactions go on in concentrated solutions along certain lines and proceed at least nearly to completion in such solutions, in dilute solutions the same law does not hold. Take, for instance, the case of manganese and sulphur. You know very well that iron sulphide is broken up by manganese; the sulphur is seized and forms manganese sulphide, leaving the iron, and the manganese sulphide then leaves them both. Now, if this reaction proceeded to completion, it should be easy, by adding an excess of manganese, to take out *all* the sulphur. But, as a matter of fact, you are perfectly well aware that this is entirely impossible; that each unit of sulphur is harder to remove than the last; and that you reach a point beyond which the addition of further manganese does not reduce the sulphur at all. I take the same to be the case in regard to oxygen, only that the equilibrium point is lower and the influence of temperature is more important, so that, if the temperature be kept moderate, the oxygen will remain to some extent, unless powerful deoxidizers are added.

In this connection I may say that we had an accidental confirmation of the correctness of the oxygen theory, which may not be without interest. By accident, one heat of the new metal was made with iron about 3.0 per cent. in manganese, so that the resulting mixture was about 1½ per cent. The strength of this iron was reduced 3000 pounds,—*i.e.,* from about 21,000 pounds to about 18,000 pounds,—on the 2-inch square bar as compared with iron identically the same in all particulars, except that the manganese was normal, or about 0.4 per cent.

There are two other questions of interest:

First.—In what respect and for what reason is this new material better than the so-called semi-steel (cast iron with a mixture of steel scrap)?

Second.—How do we achieve the advantage of high carbon, which, it is my belief, is one of the advantages of cold-blast charcoal iron for special purposes?

The answer to the first may be divided into four portions:

(*a*) The effect of oxygen is to reduce the graphite to a fraction of its injurious area, by changing its shape. This is obviously far superior to a simple dilution of the carbon, which can only reduce the graphite by about a third in the most extreme case.

(*b*) The temperature required for the melting of steel scrap is very high, materially above that of an iron with normal carbon. This requires such iron to be raised to a higher temperature than iron with normal carbon, and facilitates the elimination of any oxygen which it may contain.

(*c*) The use of steel scrap dilutes the carbon and reduces the quantity of cementite which can be formed, so that chilled castings made in this way have not the hardness and wearing qualities of those made of irons with high carbon when the latter is all combined.

(*d*) It seems certain that carbon in proper condition facilitates the machinability of an iron, remembering that this carbon is in the form of graphite, one of the best lubricants known. It has been demonstrated by experience that an iron of a given strength of matrix machines more easily if it contains more carbon, without necessarily being weaker than low carbon iron if the carbon be in more nodular form than that in the low carbon iron.

The answer to the second question is that, by the hot operation of coke furnaces with a limy slag, the carbon can be forced up to or beyond 4 per cent., and by proper operation in treating it we can preserve practically all this carbon, thereby securing an amount equal to that of the cold-blast iron. Whether we shall be able to go beyond this, and introduce additional carbon during or after the treatment, I am not able to say, because we have made no experiments along that line. It seems likely that this will be unnecessary in practice, for most of the users of cold-blast charcoal iron use it in the air furnaces, and reduce the carbon to between 3.5 and 3 per cent. before casting, an amount which we can easily exceed.

We have had a number of tests made by parties who were interested in the purchase of iron. Some of these I am not at liberty to publish, but the representative of one large railroad company has told me privately that it found the strength and chilling power of the iron to be virtually the same as that of one of the famous brands of Eastern charcoal iron. Another railroad company reported that it found the breaking strength of the iron in 2-inch square test bars on 12-inch centres to be 25,000 and some odd pounds; while through the kindness of Mr. Harry B. Swan, of the Cadillac Motor Car Company, I am able to present a table of results of crucible remelts made from this iron.

CADILLAC RESULTS.

Analysis	Combined carbon	.85
	Graphitic carbon	2.65
	Manganese	.26
	Phosphorus	.326
	Sulphur	.039
	Silicon	1.25

The test bars showed the following results from the Standard 1¼-inch round bar of the American Society of Testing Materials, on 12-inch centres (four bars gave the following results):

	A	B	C	D
Transverse strength in pounds	4,505	4,825	4,825	4,875
Modulus of rupture, pounds per square inch	67,300	67,100	67,100	66,400
Tensile strength, pounds per square inch	34,800	33,800	34,100	33,800
Brinell hardness	202	207	202	196

Charcoal iron showing above 3000 pounds on the 1¼-inch test bar is strong enough to be put into a class of special iron by itself, while one of 4000 pounds strength is very rare. You will see that this iron is about 60 per cent. stronger than the former, and about 20 per cent. stronger than the latter. The closeness of its grain you will see from the samples and from the photomicrographs (Figs 28 to 31). These latter also show the graphite in this iron to be almost completely nodular, rather than of the flake variety, and show, in the most unmistakable manner, why the iron must be stronger than an iron the same matrix, but with wide flakes of graphite. The effects of oxygen in changing the form of crystallization and in preventing the breaking down of the combined carbon are the same in this iron as they are in charcoal iron, except that worm-blast charcoal iron contains only from 0.015 to 0.30 per cent. oxygen, whereas we have no difficulty in obtaining 0.050 to 0.70 per cent oxygen, with correspondingly greater effect in these two directions.

The experiments which have been made on actual castings show also that the suppression of the eutectic is more than a scientific hypothesis. One large company found that a certain casting was extremely difficult to make of ordinary iron without having shrinkage cavities along a certain line, but that, when poured from this iron, the castings were absolutely sound at this point. This I believe to be because the iron solidifies all at once as a homogeneous mass instead of passing through a long range of progressive freezing. The last freezing or eutectic portion is that which is altered by the presence of this minute quantity of oxygen into something else with a higher melting-point.

Returning now to the iron-carbon diagram, a valuable suggestion has been made by Professor Campbell, to the effect that there are shown by Fig. 2 several paths along which iron-carbon alloys may pass in cooling; that one of these may result in one structure and another in another, and that the presence of a small quantity of oxygen may be the controlling factor which forces the cooling to take place according to one of these paths or another. This suggestion, combined with the diagrams of Guertler and Upton, goes further to account for the facts as we found them in practice than any other that has been made. The suggestion from Upton, that graphitization occurs on one side of the eutectic point below the eutectic freezing temperature and not on the other, is very much in line with the observations of practice, for it is a fact that certain irons will throw off graphite into the air in great profusion while running from the furnace, whereas other irons of similar composition and perhaps even higher in carbon will show no such tendency whatever. This is particularly true in relatively low carbon coke irons of about 1.0 per cent. silicon and relatively high carbon charcoal irons of about the same silicon. The latter scarcely ever makes any show of graphite as it runs from the furnace. The other fills the cast-house until it looks as though a black snow-storm were in progress.

You will now ask the practical questions: Granted that we have here a new material, what is it good for? What can we do with it?

The answer is that it is good where strength, closeness of grain, steam tightness, and wearing qualities are desired. Above all, it is good where chilling power under strict control and hard, strong chill are desirable. Because irons containing oxygen have this peculiarity, they not only begin to show a chill at a higher silicon percentage than do coke irons, but they are also much more sensitive to chilling influences. High oxygen iron of 1.25 per cent. silicon will show no more white chill than a coke iron if cast in sand, though, of course, it will be much finer grained. But, if cast against a chilling surface, it will show from 1/8 to 1/4 inch white chill, whereas when coke iron reaches the range of silicon within which it will "take a chill" it is with difficulty prevented from chilling, even when cast in sand. With this great strength, with this power of making intricate castings without shrinkage cavities, and with its chilling power under accurate control, it seems that the metal should find its largest field, measured in tons, in car wheels, and tests of it for this purpose are now under way. Outside of that field, the metal is particularly adapted for steam, gas, or ammonia cylinders. As a substitute for or improvement on "gun iron" for strong castings, such as are now made from the air furnace, I believe that this metal cast from the cupola will find a large field of usefulness.

It is our hope, also, that with this metal it will be possible to produce malleable castings by melting in the cupola as easily as to produce them from the air furnace, as is done in present practice, because we can supply the carbon of any amount desired, and we can also introduce the oxygen, which it is largely the function of the air furnace to put into the iron now. This statement may seem radical, but I have had made an analysis of malleable iron, and found it to contain 0.13 per cent. oxygen. Moreover, malleable iron, which under the microscope is shown to be composed of iron interspersed with little round nodules of graphite or temper carbon, is only a step beyond the metal which I have shown you, and, in my judgment, the new metal will eventually be found to constitute an intermediate step between malleable iron and ordinary cast iron. In malleable iron the carbon is all retained in the combined condition, as in cast, and is subsequently graphitized against the resistance of the solid iron by prolonged annealing. The new metal delays graphitization until the structure is sufficiently solidified to resist the formation of the graphite, the resistance being sufficient to force the latter into the forms entirely similar to those in true malleable.

Where castings are made from the maximum percentage of cheap scrap with the minimum of new iron to carry this, a softener is needed, probably in part because of the high sulphur of the mixed scrap; and as this new product tends to produce high combined carbon, and is a strengthener (and to that extent a hardener), it is not recommended for such castings. On the other hand, where a high silicon strong iron is needed, so that it may have good machinability and lend itself to rapid manufacture and yet be strong and fine grained when finished, the ideal material to give these qualities can be made by the new process, and, once the exact combination of strength and machinability desired by the foundrymen is known, that combination can be repeated under conditions of strict control to an extent not possible with any other product.

Iron from the blast furnace has to be taken as produced, not only in oxygen but in the other elements, but, by the use of a mixture of known components, in combination with this process of treatment, we are able to produce iron not only of a given analysis, but with certain physical qualities accompanying that analysis, a degree of control impossible to obtain in iron direct from the blast furnace.

DISCUSSION.

Professor A. E. Outerbridge, Jr., chairman of the meeting, after having invited discussion of the paper of the evening, gave informally a *résumé* of various investigations that have been made by eminent scientists on the condition of carbon in iron. He said that pure carbon is known in several allotropic forms; thus we have in the diamond the most pellucid and hardest of all crystalline substances. Ordinary lampblack (also pure carbon) is the most opaque substance known to rays of light. Graphite is still another form of carbon, differing in many ways from the other well-known forms. Ordinary cast iron contains from 3½ per cent. to 4 per cent. of carbon; this is usually partly combined with the iron and partly graphitic, the relative proportion of each determining, in large measure, the physical properties of the metal, subject, of course, to controlling influences exerted by silicon, manganese, and other elements.

When white cast iron (a metal having nearly all of its carbon in the combined form) is subjected to a very high temperature for many hours the carbon gradually separates from its combination with the iron and becomes "free" carbon, but examination shows that this free carbon is disseminated throughout the iron in much smaller particles than the flaky, graphitic carbon of ordinary cast iron, and it has been christened "Ledebur's temper carbon," to distinguish it from the free carbon naturally existing in cast iron.

There is a vast difference in density, strength, homogeneity, and ductility between ordinary cast iron containing, let us say, 3½ per cent. of free carbon and annealed white iron containing about the same amount of temper (free) carbon. A cubic foot of this annealed iron will weigh fifty or sixty pounds more than a cubic foot of ordinary gray cast iron.

The tensile strength is at least 50 per cent. greater, the metal is much more homogeneous, and it is to a considerable degree malleable. Ordinary grey cast iron will continue to increase in cubical volume (or "grow") after repeated heating and cooling to the extraordinary extent of 50 per cent. or more. White cast iron converted into grey iron by heat treatment will not increase in bulk sufficiently to overcome the original shrinkage of the metal in passing from the liquid to the solid state after repeated heating and cooling.

The foregoing facts are mentioned here for the reason that Mr. Johnson claims that the carbon in his iron that has been partially refined by a pneumatic process is distributed in small balls instead of in flakes, as in ordinary cast iron, and may serve to show that there is nothing inherently opposed to experience in his statements in this respect.

Furthermore, we know that when steel or wrought iron scrap is melted with cast iron in proportions ranging all the way from 5 per cent. to 30 per cent. or more we obtain a metal which is exceedingly dense and strong; the free carbon is evenly distributed in very small particles, providing there is sufficient silicon present to prevent the permanent combination of the carbon and the iron. Sterling's "toughened cast iron," patented in England in 1848, was produced by melting wrought iron scrap with cast iron in a cupola. In recent years this metal has been incorrectly called semi-steel." The carbon is distributed throughout the iron in very fine particles.

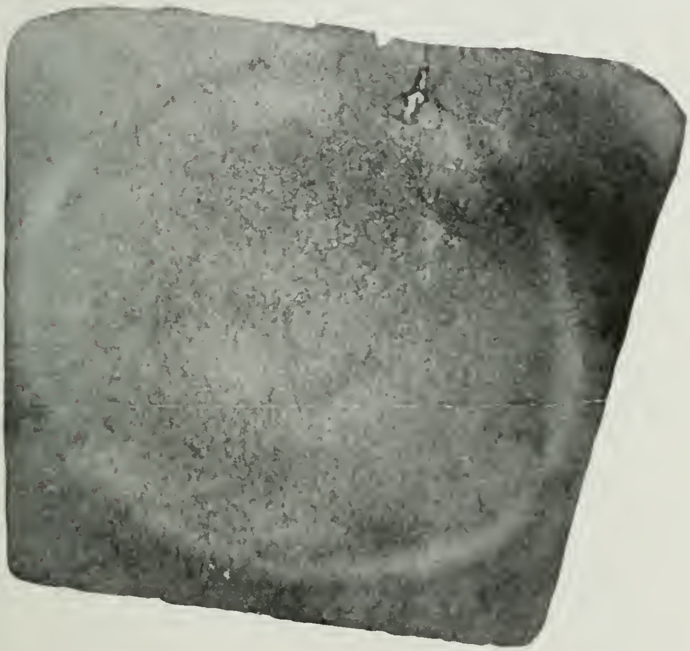
About twenty years ago Wahl and Greene lined some ladles with powdered hematite ore, into which they poured molten, soft cast iron having tensile strength of about 20,000 pounds per square inch when cast in bars 1 inch square section 15 inches long. Violent ebullition occurred with the formation of slag, caused by the oxygen uniting with the carbon silicon and other oxidizable elements in the iron.

The slag was skimmed off and the metal poured into similar test bars; these were turned and pulled, showing tensile strength of more than 30,000 pounds per square inch. The metal was exceedingly fine grained, dense, and much harder than the same iron untreated.

Some experimental castings were made from this treated metal, and all contained blowholes, attributed to the presence of dissolved iron oxide. No practical use was made of this method of changing the character of molten cast iron, so far as I know. Whether Mr. Johnson's method of burning out silicon and then restoring that element to cast iron will prove successful or not in practice, in producing coke iron of quality superior to charcoal iron, we are, nevertheless, indebted to him for an interesting and valuable paper on the subject.

Mr. H. V. Wille (*Metallurgist, The Baldwin Locomotive Works*): Mr. Johnson appears to have produced a coke iron having characteristics similar to a charcoal iron. It is generally admitted that a charcoal iron has superior chilling qualities and has greater strength than a coke iron. The carbon in the form of charcoal appears to be more soluble in liquid iron than carbon in the form of coke, and there seems to be a further effect; that is, a greater amount of the carbon remains in solution in the charcoal iron during the process of cooling. Therefore the resultant casting or test-piece has a high percentage of combined carbon, and is, consequently, of greater strength than the usual accepted theory, and maintains that the shape, condition, and even quantity of the graphite crystals in an iron are affected by the amount of oxygen present. Personally, I cannot reconcile the presence of free oxygen with such powerful deoxidizing agents as free carbon, silicon, manganese, vanadium, or titanium. It seems to me that the process proposed by Mr. Johnson is largely a purifying process, and by means of this process he secures an iron having low sulphur with relatively low silicon. He removes the silicon and, no doubt, a considerable quantity of carbon from a portion of the iron, and then adds to this semi-purified iron an additional coke iron. Mr. Johnson, however, controverts this generally quantity of blast-furnace iron, so that the resultant iron has a comparatively low silicon and low carbon, and it necessarily is a harder and stronger iron than a straight blast-furnace iron. It seems to me, however, that the time to purify an iron should not be after it leaves the blast furnace, for the results of such purifi-

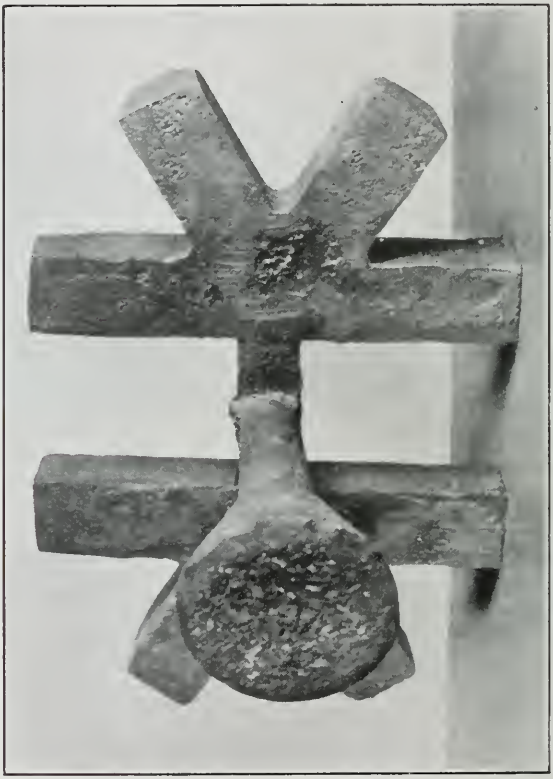
FIG. 1.



cation will no doubt be greatly modified by melting the iron in a cupola in the presence of large quantities of coke and limestone, It would be better to purify such iron after it leaves the cupola and immediately before it is poured into the mould.

As a result of some experiments which I will later describe, at my suggestion Mr. Carl Hering treated cast iron in an electrical furnace, with the result that the product was much harder, stronger, and denser than an ordinary cupola iron. We also experienced the same results with iron melted in a tilting open-hearth furnace at the Standard Steel Works. This iron was extremely hard and close grained, showing that any purifying process, or any process which will reduce the silicon or carbon, will result in a harder iron. These experiments indicate that it

Fig. 2.

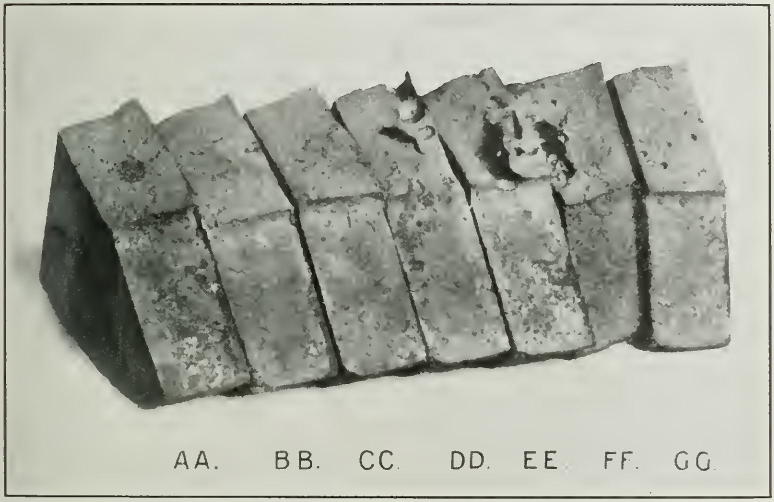


is not necessary to accept the oxygen theory in order to explain the greater strength of an iron treated by Mr. Johnson's process.

The internal chill described by Mr. Johnson has been produced by Keep and others by simply immersing a cylindrical test-piece in water after the outside has cooled and while the interior is still liquid. This experiment can be repeated by any one, and it demonstrates that the iron can be chilled only while still liquid. A photograph of a chill so produced is shown in Fig. 1.

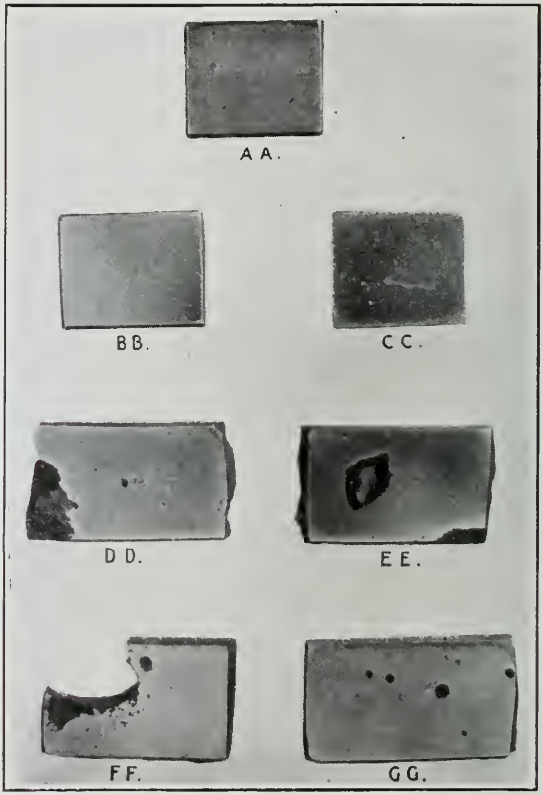
I will pass over a discussion of the effect of the various metalloids on the physical properties of cast iron, but in 1896 I made a very extensive investigation into the effect of carbon, phosphorus, sulphur, silicon, and manganese on cast iron. They confirm, in a general way, the views set forth by Mr. Johnson, and especially do they confirm the statement that combined carbon has the most profound effect on cast iron. As a result of these experiments we discontinued entirely the analysis for graphite, and confined our efforts to determinations of combined carbon, and these views are now generally accepted and very few manufacturers make determinations for graphite except for experimental work.

FIG. 3.



I take this occasion to call attention to a valuable article on liquid contraction of cast iron by Hailstone,[1] published as the Carnegie Memoir by the Iron and Steel Institute. The object of the investigation was to discover why iron castings which appear solid on machining develop leakage under hydrostatic test, and the inability to trace the defect by means of chemical analysis. A special type of test-bar was employed, which resembled in general the letter "K," a photograph of which I am showing (Fig. 2). These bars were poured at intervals from a ladle, so that the various test-bars were poured at different temperatures. It was found that the iron underwent a profound change, and that

FIG. 4.



---

[1] Carnegie Scholarship Memoirs, vol. 5, 1913, p. 51.

after passing a critical point it seemed to be very definite and pronounced. The experiments further show that with low pouring temperatures there is a corresponding decrease in hardness, density, and strength, and that blowholes appeared only in castings poured at a low temperature. I am showing fractures of these test-bars poured at various temperatures.

FIG. 5.

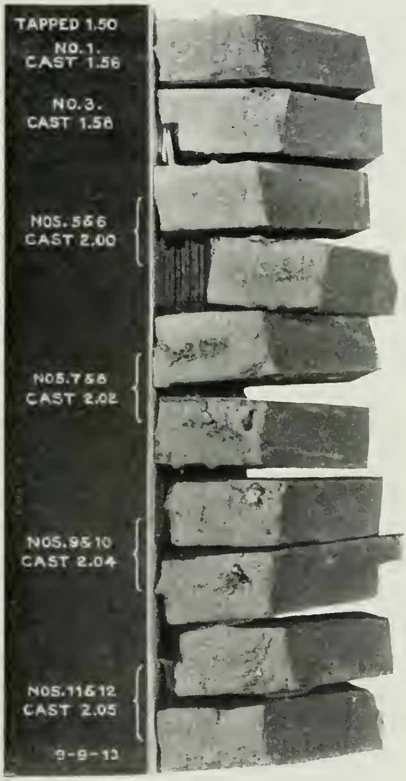
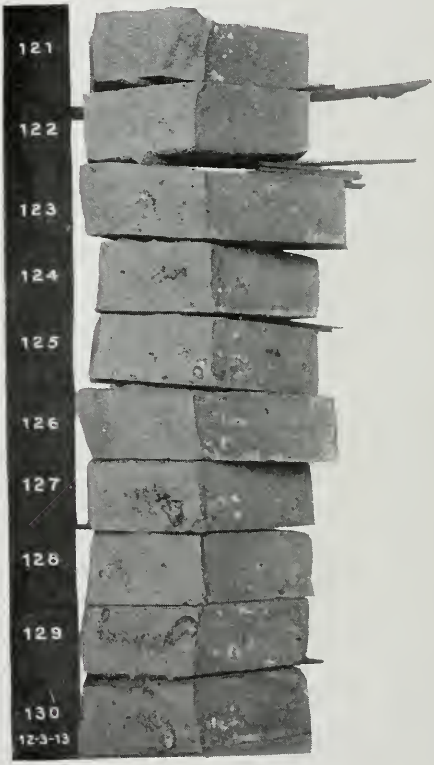


Fig. 3 shows the results of Hailstone's experiments. Test-bar *AA* was first cast, the other bars being cast at successive intervals of from one to two minutes, test-bar *GG* being cast 6½ minutes after test-bar *AA*. It will be noted that *AA*, *BB*, and *CC* are free from blowholes or liquid contraction, whereas *DD*, *EE*, *FF*, and *GG* contain gasholes and blowholes. Hailstone's analysis gives the gas evolved in heating these specimens for 12 hours at 950° C., and in no instance did he report the presence of any oxygen whatever, the constituent gases being CO and H_2N_2. He further reports a gradual decrease in the volume of the gas generated with a decrease in the pouring temperature.

Test-bar *AA* contains .392 cubic centimetre per gramme, while sample *GG* contains .096 cubic centimetre per gramme. He further reports an increase in the size of the graphite crystals in the constant decrease in the strength of the iron in the samples that were poured cold at a low temperature. These elaborate and scientifically conducted experiments would seem to have a direct bearing upon Johnson's experiments. The casting temperature is undoubtedly increased by Johnson's method, which, in the light of Hailstone's experiments, would seem to have a more

Fig. 6.



direct bearing on the quality of the product produced than the possible presence of oxygen. Furthermore, Hailstone shows by actual measurements that the graphite crystals are smaller in the hot-cast test-piece than in the cold-cast test-pieces, so that the difference in microstructure reported by Johnson can also be explained by a mere difference in casting temperature. This explanation of the results obtained by Mr. Johnson seems much more rational than that proposed by him.

FIG. 7.

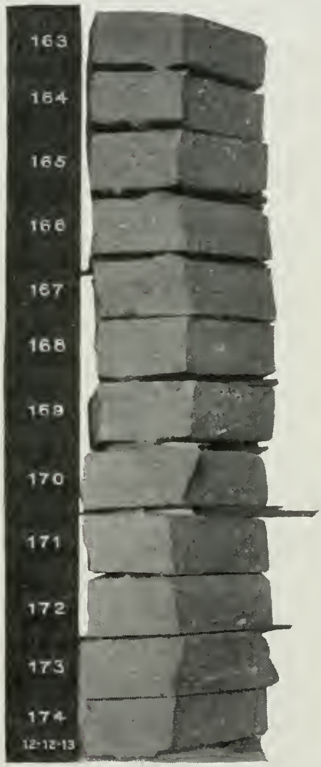


Fig. 4 shows a sectional view of Hailstone's test-bars.

Fig. 5, 6, and 7 show a practical application of Hailstone's experiments in an iron foundry. The time the iron was tapped and the time of pouring the test-pieces are shown in the various figures.

Fig. 5 shows an ordinary heat of iron, the first bars cast being free from defects, whereas those cast after the iron had an opportunity to cool show the effects of liquid contraction.

Fig. 6 shows a cold heat of iron, and practically all the test-pieces contain defects, whereas Fig. 7 shows a hot melt of iron, in which all of the test-pieces are free from defects. These results would indicate that many of the internal defects in cast iron could be eliminated by superheating the iron in a fore-hearth after it is tapped from a cupola. This superheating could best be done by an electrical furnace, and the small amount of heat which it is necessary to impart should not greatly increase the melting cost of the iron.

CLOSURE BY THE AUTHOR.

In spite of my regard for the investigations and achievements of Professor Outerbridge, I am compelled to differ with his understanding of my explanation of the action which takes place by the introduction of oxygen into iron. The process is in no degree a refining process, because, while silicon is taken out, it is restored by the addition of the untreated metal, and the carbon is scarcely affected at all. The fact that the process is a pneumatic one has no bearing whatever on the subject. We could as well introduce the necessary oxygen by the use of an oxidizing slag or perhaps by one or two other methods, but these would not be quite so convenient, and would not be under the strict control of the Bessemer, and therefore would not be as good practically.

I have tried to make clear the difference between my iron and semi-steel, so called, and to point out that, while that material may be made strong, this is done at the sacrifice of the carbon, which is bad both for chilling purposes and for machining.

In regard to Mr. Wille's discussion, while I am in agreement with the major portion of it, I am compelled to differ with his statement of the reason for the superiority of charcoal over coke iron. It is true that charcoal is more soluble in iron than coke, or at least that charcoal irons are apt to be higher in carbon than coke irons, but I have tried to make it very clear that this high total carbon falls out of combination and turns to the graphitic form more than lower total carbons. It is true that good charcoal irons retain a larger portion of their carbon in the combined condition, but this is entirely due to the presence of oxygen in them.

since we have repeatedly proved that irons high in carbon, without oxygen to prevent its precipitating out, are poor almost to the point of being worthless.

I must explain that Mr. Wille has received a wrong impression in regard to one matter. We are particular *not* to remove very much of the carbon, and owing to the laws of chemistry we are very successful in retaining it in the iron, because at the low temperatures which we use the silicon almost all disappears before the carbon begins to burn, and we have, therefore, only to stop the blow to retain almost all the carbon. We have recently made irons containing as high as 3.8 per cent. of this element, and hope to do better than this when we have obtained better facilities.

Mr. Wille finds it impossible to believe that oxygen can remain in molten iron in the presence of such strong dioxidizers as silicon, manganese, and carbon. This point of view is not surprising, and was at one time very strongly held by no less an authority than Professor H. M. Howe, but on more careful examination this fact is seen to be in line with a vast array of other facts dealing with dilute solutions, since it has been abundantly proved that reactions which go to completion in concentrated solution do not go to anything like completion in dilute solutions as an equilibrium point is reached before the reaction is concluded. This is the case in regard to oxygen and also in regard to sulphur to about the same extent. It is well known that sulphur is slagged out by manganese, and that the weight of manganese required is only about twice that of the sulphur when the two are chemically combined, which would mean that for ordinary iron less than 0.2 per cent. manganese would be required for the complete elimination of the sulphur. But we know, as a matter of fact, that this is not true; that it does not begin to be true. Two or three times this amount of manganese is required to make a substantial reduction in the sulphur, and this reduction soon reaches a practical maximum which no further addition of manganese will increase. So it is with oxygen: at a certain temperature 3.8 per cent. carbon and, say, 1.25 per cent. silicon will eliminate all the oxygen down to about 0.06 or 0.07 per cent.; if the temperature be raised or if manganese be added, this quantity will drop until there may be as little as 0.01 per cent. oxygen remaining, or even less. But as to the actual presence of oxygen in iron there is no room whatever for doubt. After many months of careful research work carried on by one of the best chemists I have ever known, we were able to reach conclusions which have since been abundantly checked by analyses made for me by the American Rolling Mill Company, which has a very large research laboratory, and which has specialized in oxygen determinations.

In regard to the internal chill of spotted iron there is also, I think, a misapprehension. I have seen such an internal chill produced, and it is in the way that Mr. Wille describes, by quenching a casting whose interior is still molten after its exterior has been allowed to harden in the air. But a spotted iron does not require this or any other treatment to show its characteristic " spot," which, by the way, is entirely different from the appearance of the internal chill produced as described. Not only is no treatment necessary, but no treatment of which we have knowledge is sufficient to prevent the formation of the spot, unless it may be extremely slow cooling. This spot is due to the concentration of the carbon at the centre of the pig, forming a eutectic or easy-melting substance at that point which stays liquid until the iron around it has become so rigid and has contracted upon it so tightly that the expansion which would occur on the formation of graphite cannot take place, and the carbon is therefore held in the combined condition.

The effects of pouring temperatures are undoubtedly very important; but it will be observed that in our experiments we completely eliminated the possibility of the results we obtained being due to a variation in pouring temperature by making remelts of the strong irons and weak ones in crucibles which prevented any substantial alteration in their composition, and we found that their characteristics were preserved absolutely on remelting. It is therefore absolutely impossible to attribute the results which we have achieved to any change in the melting temperature, and incidentally I would like to say that we do not raise the melting temperature of the iron, as stated by Mr. Wille. On the contrary, we take the pains to blow the iron cold and to keep the temperature just as low as we can without danger of skulling, throughout the operation; we cannot get the best results by any other method. But after the iron is once made it can be remelted as hot as desired, within reason, without injury.

In conclusion I would like to say that I think the doubt remaining in the minds of Messrs. Outerbridge and Wille as to the possibility that oxygen is accountable for the results described is due to the fact that it was impossible in a lecture to take the time to make a complete presentation of this subject. If they would study the data given by me, and those given in my paper, "The Effect of Oxygen, Nitrogen, and Some Other Elements on the Quality of Cast Iron," before the American Institute of Mining Engineers, and also the very remarkable results which we have been able to obtain by no other changes in the composition save the content of oxygen, I am sure they would be convinced that this element, and this alone, is accountable for the results which we have obtained. The many facts of practice, such as the use of the air furnace with the oxidizing flame for the production of strong castings, and the irons of remarkable strength produced from the blast furnace when oxidizing conditions and low temperature prevail in its hearth, furnish ample confirmation of the oxygen theory, but an insuperable obstacle to any other now existing, and I have little doubt that Mr. Wille and Professor Outerbridge will ultimately accept the former as our knowledge of this subject grows.

Paraffin Wax Industry of Austria. P. PORGES. (*Z. Angew. Chem.*, xxvii, iii, 41.)—To enable Austrian lubricating oils to compete with Russian and American oil the paraffin wax is separated as completely as possible. About 95 per cent. of the Austrian works use the patented apparatus of Porges, Singer, and Steinschneider, and produce 6500 wagon-loads of purified wax per annum. The oils are gradually chilled by passing them through a series of connected crystallizing chambers surrounded by coils through which brine is pumped. The semi-solid mass from the chambers is pressed, usually in filter presses, and the filtrate again partially chilled before being suitable for lubricants. The residue in the press, termed "gatsch," is usually submitted to dry sweating to expel the oil. A recent improvement is the introduction of Pejzel's apparatus, in which the sweating vessels are mounted on trolleys which pass through a ventilated passage. After leaving the sweating vessels the wax is decolorized with sulphuric acid and "silicate." The system of moist sweating, which is little used, aims at utilizing the hot liquor from the crystallizing chambers. Fractional crystallization of the wax is effected by chilling the chambers in stages. One part of the apparatus works at 0° C., a second at $-5°$ to $-7°$ C., and a third at $-10°$ to $-18°$ C.; and in a patent process of Pejzel and Porges each chamber is chilled so as to yield a paraffin wax of a definite melting-point.

Repainting Tests on Paint Oils. HENRY A. GARDNER. (*Circular No. 30,* Paint Manufacturers' Association of the United States.)—In May, 1911, there was exposed at Washington a series of wooden panels painted white. The pigment mixture used in the paints was the same for each test, but the liquid portion of each paint was varied. The tests were made in order to determine the relative durability of various oils as paint vehicles. Complete information was given in a paper entitled "The Practical Testing of Drying and Semi-Drying Paint Oils," as presented before the American Society for Testing Materials (*Proc. A. S. T. M.*, 1911, p. 641). The tests have now been repainted. At definite periods, previous to repainting, photographic records of the appearance of each paint were made. This accumulated data will be available when the repainting tests have sufficiently weathered. Previous to repainting, the surface of each panel was lightly sanded to remove any surface defects. The paint was then applied directly to the panels upon the exposure rack. Five per cent. of drier was added to each paint. For the first coat, reduction with a pint of turpentine to a gallon of paint was made. The second or finishing coat was applied without reduction. A period of one month was allowed for drying between coats. As none of the paints used for the original painting of the panels had been reserved, it was necessary to make up another quantity of each for the repainting tests. For this purpose a quantity of the original white pigment mixture, ground to a stiff paste in fourteen parts of raw linseed oil, was prepared. Many of the oils used in preparing the different paints for repainting were portions of the quantities originally used in the first set of paints. Analysis of these oils shows that some action has occurred in them during the last forty-two months, their constants in some cases varying from the constants shown when the oils were first analyzed. In a previous investigation the writer has pointed out the effect of enzymes upon oils and oil-paste paints, and has shown that such effects may be inhibited by sterilization. A series of experiments designed to throw more light upon this question is now under way.

Nickel-plating Aluminum. ANON. (*Metal Ind.*, xii, No. 9, 378.)—M. Le Chatelier has just presented a communication to the Académie des Sciences, stating he has succeeded in nickel-plating aluminum, which has not been accomplished by the ordinary methods. This has prevented the extensive employment of the metal on account of its dull appearance. This difficulty has been surmounted by a preliminary scouring of the aluminum in a bath of hydrochloric acid containing a certain proportion of iron. The iron precipitated on the surface of the aluminum forms a kind of network, and when the metal is passed into a nickel bath the nickel gets entangled in this network and adheres strongly to the aluminum. This process, which is based on a physical action, appears to solve the problem which had been considered insoluble hitherto.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

PRINTING INKS.†

THE purpose of this circular is to give a general description of the composition, manufacture, and properties of some of the common types of printing inks.

The materials entering into the composition of printing inks are divided roughly into two classes, viz., oils and pigments. The first class includes linseed oil, rosin oil, the various semi-drying oils, gums (resins), rosin, and soap. The second class includes the various pigments from which the inks derive their color, and, to some extent, their consistency and working qualities. A brief description of the preparation and properties of these materials is given. The subject of driers is treated in a separate chapter. Various formulas are given showing the approximate composition of some inks.

The manufacture of printing inks is described, showing the method of preparing the oil varnish and pigments, the methods of mixing and grinding, etc.

The circular then takes up the question of the relation of ink to the paper. To obtain satisfactory results in printing, these two factors, ink and paper, must be carefully adjusted. It is well known that an ink which is satisfactory on one paper will not be so on another, all other conditions being constant. One phase of this relationship between ink and paper is the opacity of the ink, a subject of particular importance in the three-and-four-color processes. Emphasis is laid on the necessity for the printer to select the proper grades of paper which will be suitable for his work.

The question as to what constitutes a good ink is often asked, and, while this circular does not pretend to answer this directly, it gives the requirements and tests specified by the Government

---

* Communicated by the Bureau.

† Circular No. 53.

Printing Office, which show how one government department is handling this problem.

The Bureau of Standards has issued a technologic paper on the subject of the analysis of printing inks, an abstract of which is included in the circular. The application of these tests and their relation to the practical tests under working conditions are given.

Owing to the importance of linseed oil in printing inks, a special chapter is devoted to the manufacture and properties of this oil.

A bibliography on inks, oils, and pigments is included for the benefit of those who wish to make a deeper study of the subject than the general nature of the circular permits.

REGULATION OF ELECTROTYPING SOLUTIONS.*

THIS circular has been prepared to meet the demands of electrotypers for such information as is available on the operations involved in copper and nickel electrotyping. Owing to the small amount of scientific information available upon this subject, this edition of the circular is confined to a general discussion of the possible results of such work, and to simple methods for testing and adjusting the acid copper sulphate electrotyping baths. A preliminary study of the problems of electrotyping is now being conducted by the Bureau of Standards in coöperation with a special committee of the International Association of Electrotypers. From the results of this preliminary work it is hoped to outline and conduct a more exhaustive investigation of these problems.

EXCERPTS FROM THE REPORT OF THE DIRECTOR OF THE BUREAU FOR THE FISCAL YEAR ENDING JUNE 30, 1914.

SINCE the Bureau of Standards deals almost entirely with scientific and technical problems, the following brief statement as to its functions and organization may be of assistance to those who are more or less unfamiliar with its work.

The standards with which the Bureau is authorized to deal may be conveniently classed as follows: First, standards of measurement; second, standard values of constants; third, standards of quality; and, fourth, standards of mechanical performance.

---

* Abstract, Circular 52, issued January 25, 1915.

I. STANDARDS OF MEASUREMENT.

A standard of length may be taken as an example of a standard of measurement. It must be a length which is unchanging, reproducible, and capable of being compared with the working standards used in the most precise scientific work or with those used in commerce and industry. The fundamental standard must be subdivided and working standards prepared of these parts; for the measurement of greater lengths, standards must be prepared which are multiples of the fundamental standard. This process of subdividing and multiplying the standard involves even more difficulties than those met with in the preparation of the fundamental standard itself.

The construction of a set of standard weights from a single unit is also an illustration, but a whole set of standard weights must be prepared before the standard weight of the Government can become available to the public. When the standard of length or weight has been found with as many desirable qualities as possible, and before the working standards of the subdivisions or multiples can be prepared, the question as to the method of comparison arises which again involves the solution of difficult scientific problems in connection with the balance or the methods used. These balances range from that capable of measuring the thousandth part of a milligramme to the large testing machine capable of measuring a load of thousands of tons. The complete range must be covered, which involves not only a large number of working standards, all of which must agree with the fundamental standard, but apparatus suitable for the comparison of these standards with all of the lengths or weights found in practice.

These steps and equipment are absolutely essential in order to secure uniform measurements of length or weight throughout the country, and they have their counterpart in every quantity that has to be measured, whether it be length, weight, temperature, heat, light, or the various electrical measurements or other standards of measurement. These standards in one form or another are involved in practically every scientific investigation, industrial process, or engineering structure.

2. PHYSICAL CONSTANTS.

There are many fixed relations between physical quantities, the values of which it is extremely important to know. These values are usually termed "physical constants," and are used in every branch of scientific work or industry. The amount of heat required to change a pound of water into steam under normal conditions and the relation between heat and mechanical energy are two important physical constants; their values are used in practically every computation in connection with the designing of steam engines and boilers, the tests of their efficiencies or the measurement of their output. The amount of heat required to turn liquid ammonia into vapor or the amount of heat required to melt a pound of ice are constants equally important in the refrigerating industries. The value of the relation between electrical and mechanical energy is involved in many important commercial transactions concerned in electricity.

Accurate and authoritative values of these constants are just as essential as in the case of standards of measurement. Many of these now in use are old and obsolete and need redetermination by means of the best modern facilities for physical measurement. Their determination involves the most difficult and precise work in all branches of physics and chemistry—a fact not generally known by others than those engaged in the scientific and technical work where these constants are used.

3. STANDARDS OF QUALITY.

A standard of quality for a given material may sometimes take the form of a sample of that material with which other materials of the same kind can be compared, but this is generally a makeshift of the poorest sort. It is only resorted to in the absence of definite and reliable specifications in terms of measurable properties; that is to say, a standard of quality of a material usually takes the form of a specification or definition of its properties, involving, of course, the measurement of those properties by means of the usual standards of measurement. A certain kind of steel, a cement, a paint, an oil, or a paper or cloth is found by use to be good or poor. The question then arises, Why is it good or poor; what are the physical or chemical properties or the particular combination of elements which make it of good or poor quality; how are its properties to be measured or its constituents determined? These are questions for the laboratory to answer, and involve physical and chemical investigations of the most difficult sort.

A standard of quality for a given material necessarily takes into account the purpose for which the material is to be used; to set the standard too low results in losses, poor efficiency, and even loss of life; to make it too high may result precisely in the same thing; that is to say, the material must be suitable for the purpose intended, and the Bureau's investigations in connection with the properties of materials are to enable the user of these materials, first, to select intelligently the material best suited for the purpose; second, to specify it in terms which the producer cannot mistake; and, third, to make the necessary tests to ascertain whether or not the material supplied is in accordance with the specifications.

The actual testing of materials by the Bureau of Standards to ascertain whether or not they comply with specifications is confined almost exclusively to Government purchases, but in making these tests (in which the Bureau has had the hearty coöperation of practically all the departments of the Government service) it is compelled to make many investigations concerning the properties of materials, their specification and measurement. While this work is of great value in placing Government purchases on a correct business basis, the results of the investigations as to the properties of materials and the information gained in testing Government supplies are even more important to the general public, and are distributed in the form of suitable publications.

The Bureau does not compete with private testing laboratories, but endeavors to assist them by the development of standard specifications, methods of measurement, and other matters where uniformity is desirable, much of which information, as stated above, is secured in connection with the testing of materials purchased by the Government and a close observation of their use.

The time is not far distant when it will be required that all materials bought or sold shall be as represented, but it should be kept in mind that this is impossible except in the case of those materials where proper standards of quality and methods of measurement have been developed. It must not be assumed that the purchaser or user is the party principally benefited in the development of such standards; on the contrary, the manufacturer, first of all, is interested in the quality and all things which affect the quality of his product, and, while the Bureau's efforts in this field are devoted principally to the pointing out and measurement of those properties upon which the quality of the materials depends, it is to be regretted that its force and equipment are insufficient to render more assistance to manufacturers with a view to a direct improvement of those parts of the process upon which the quality of the output depends.

4. STANDARDS OF PERFORMANCE.

The value of an instrument, device, or machine almost always depends upon the efficiency of its performance. In such cases it is necessary to state the performance desired or guaranteed in terms which are correct and susceptible of measurement. As in the case of standards of quality, the standard involved is more often in the form of a specification, but specifications are useless unless based upon correct scientific and mechanical principles and supplemented with a statement of the method to be used in ascertaining whether or not the specifications or guarantees have been complied with.

The performance of an engine or boiler, a pump, an electrical generator or motor, a weighing device, or a telescope can usually be measured, but the quantities to be measured and the method used must be specified correctly and understood by all the parties concerned in the construction, purchase, or use of such apparatus. To do this properly involves the use of standards of measurement, standard values of constants, and standards of quality. The Bureau of Standards does not attempt to cover this field completely, but only those cases where there is a lack of definite information upon which to base specifications, and only to the more important classes of apparatus. To secure this information involves investigations quite as scientific in character and as difficult as in the case of other standards, as well as a knowledge of technical and manufacturing processes.

The Bureau's activities in this field have only been developed to a slight extent and almost entirely in connection with Government purchases. It has had in this, as well as in the field of the properties of materials, the most hearty coöperation of the various

Government experts, manufacturers, engineers, and technical societies.

Government purchases are not greatly different from those of the public. Whenever the Bureau makes a scientific investigation or secures information from other sources for the purpose of the improvement of specifications used in connection with Government purchases, whether for measuring instruments or for materials or equipment, such information or data are given to the public in the form of suitable publications. The value of this information from the stand-point of the public is even greater than that in connection with Government purchases, important as the latter is. In other words, the needs of the public and the Government service are precisely the same so far as standards or specifications are concerned, whether it be standards of measurement, quality, or performance.

In the case of the public, the Bureau confines its work to those investigations, experimental or otherwise, which enable it to give intelligent advice regarding the use, purchase, and testing of the more important apparatus and materials, leaving the testing to commercial laboratories; except, of course, in the case of standards of measurement, where it is absolutely essential that the standards of the public be compared with those of the Government to secure uniformity of measurement, and in unusual cases of testing where the public is not yet provided with suitable means or equipment. In the case of the Government, the Bureau goes further and serves as a testing Bureau for the various departments when called upon, and as such is assisting to place Government purchases upon an economical and business-like basis. The example of the Government in such matters has a far greater influence upon the public than most people suppose. The Government can do no greater service to the country than to place its own purchases on a basis which may be taken as a standard by the public at large.

5. RELATION OF THE BUREAU'S WORK TO THE PUBLIC.

It is perfectly obvious, even to one unfamiliar with the subject, that the maintenance on the part of the Government of correct standards of measurement or quality or performance calls for continuous scientific and technical investigations of the highest grade, involving the most competent expert services and the best scientific equipment. When this is accomplished, there still remains the serious problem of making the results available and useful to the public.

The Bureau compares with its own standards of measurement the standards or measuring instruments of States, cities, scientific laboratories, educational institutions, manufacturers, Government bureaus, or the public, for which a nominal fee is charged, except in the case of the National and State Government institutions. It gives advice concerning these standards or their use, whether it be in connection with the enactment of laws, regulations, or ordinances concerning the weights and measures of everyday trade or in connection with precision standards used in scientific work and the industries. It gives advice upon request to State and city officials, public-service commissions, public-utility corporations, regarding the standards of measurement, of quality or performance, involved in legislation or regulation pertaining to the public utilities. Many questions of disagreement between the public and utility companies as to these matters are referred to the Bureau for advice or adjustment, often avoiding unfair or inconsistent regulations, as well as long-drawn-out and expensive litigation. There is a great need on the part of the public for unbiased and reliable information pertaining to the standards entering into the regulation and sale of the services of public utilities. So far as possible such information is given in the form of publications upon definite subjects.

It must not be inferred from the above that the Bureau's activities are devoted principally to the interests of the user or consumer. The fundamental facts regarding standards of measurement, quality, or performance are the very things which most deeply concern manufacturers; they are fundamentally concerned, either directly or indirectly, with the improvement of methods of production or the quality of the output. It may be said that the Bureau occupies somewhat the same position with respect to the manufacturing interests of this country that the bureaus of the Agricultural Department do to the agricultural interests. Many industries are just beginning to realize the importance of precise methods of measurement and scientific investigation, which, in practically every case, involve some kind of measurement.

It is upon quality as well as upon price that competition must finally depend, whether in domestic or foreign commerce. The use of exact methods and scientific results is the greatest factor in the improvement of quality, efficiency, or the development of new industries. The educational value of the Bureau's work in this respect is almost entirely unknown to the general public, and yet the Bureau receives hundreds of letters, as well as many personal visits from manufacturers, seeking information as to standards of measurement, how to use them, how to measure the properties of materials, or as to the fundamental physical and chemical principles involved; also, what is of even greater importance, how to initiate and carry out scientific investigations and tests on their own account in their particular fields of work.

The importance of maintaining scientific institutions having to do with standardization and the application of precise measurements to the industries has been recognized by all the leading countries of the world. Great Britain maintains the Standards Department of the Board of Trade, which is in charge of the standards and inspection service of the trade weights and measures; also the National Physical Laboratory, whose functions include matters pertaining to scientific and technical standards, physical constants, and to some extent the properties of materials. The Laboratoire d'Essais, of France, while not as extensive as the English institution, is charged with similar duties. Germany maintains three such institutions—the Normal-Eichungs Kommission, equipped with the buildings, personnel, and apparatus necessary in standardizing and controlling the weights and measures of trade; the Physikalisch-Technische Reichsanstalt, covering testing and investigations in connection with scientific and technical standards other than weights and measures; and the Prussian Government maintains the Material-prüfungsamt, a large institution devoted to the investigating and testing of structural, engineering, and other materials.

It is generally recognized that these institutions have been exceedingly important factors in the industrial progress of these countries.

Electric Field of the Sun. H. DESLANDRES. (*Comptes Rendus,* clviii, 1137.)—This is a discussion as to the possibility of certain phenomena exhibited by the solar atmosphere being wholly or partly due to the Stark effect. Attention is drawn to the differences shown by laboratory experiments between the Stark electrical effect and the Zeeman magnetic effect.

Petroleum Exhibit, Panama Pacific International Exposition.—The United States Bureau of Mines is preparing an exhibit of petroleum and the petroleum industry for the exhibition to be held in San Francisco, beginning February 20. The principal part will be located in the open, the space belonging to the Department of Mines and Metallurgy, and will cover about 52,700 square feet of ground.

An auxiliary exhibit will be installed in the Palace of Mines and Metallurgy, which will include a large collection of mine products from many oil fields of the United States and abroad.

A second auxiliary exhibit will be installed in the Palace of Machinery, where a large number of typical fuels, lubricants, and materials used in modern machinery practice will be shown.

The petroleum exhibit will consist of nine principal divisions, as follows: (1) A pictorial display, (2) a geological display, (3) a statistical exhibit, (4) a library of petroleum literature, (5) a technological exhibit, (6) the display of a large collection of crude and refined products, (7) an exhibit displaying housing and sanitary problems, (8) lectures, (9) an exhibit displaying fire hazards and methods of preventing and fighting fires.

The World's Petroleum Congress is scheduled to meet October 25–30 in the exhibition city, and will be attended by all persons interested in the petroleum industry. A number of technical and scientific papers from Americans and foreigners is assured, and the programme will be divided into several divisions. Special excursions to the great petroleum fields of California and Oklahoma are being arranged.

Coal for Coke. ANON. (*Metal Ind.,* xii, No. 10, 429.)—In the last five years the coal used in metallurgical coke manufacture has averaged around 65,577,000 tons, yielding 43,983,000 tons of coke, valued at $111,736,000. Of this total, 14,767.000 tons were used in by-product coke ovens, yielding, besides the coke, 54,491,000 cubic feet of gas, 94,306,000 gallons of tar, and $9,109,000 worth of ammonia. When it is considered that every year approximately four times these enormous totals of by-products are absolutely wasted through the use of non-by-product ovens, the vital importance to the country of a general use of the modern, scientific by-product ovens will be appreciated.

Purifying Copper. (Brit. Patent 6286, of 1913; *Elect. Engineering,* x, 216.)—According to the General Electric Company (U..S. A.), copper of a high degree of purity is obtained by melting the copper above a mixture of inert material and boric anhydride. The temperature is kept at about 1300° C., while the boric anhydride is kept beneath by the inert material and the mass is stirred until the boric anhydride rises to the surface. The process may also be applied to silver, gold, etc.

THE FRANKLIN INSTITUTE

ANNUAL MEETING.

(Abstract of Proceedings.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 20, 1915.

DR. JAMES MAPES DODGE *in the Chair.*

Additions to membership since last report, 9.

Mr. George R. Henderson presented the report of the Committee on Science and the Arts.

The tellers of election, Messrs. Jennings, Cullen, and Colvin, submitted the report of the ballots cast for President, Vice-President, Treasurer, and members of the Board of Managers, and the following gentlemen were declared duly elected to the respective offices:

Walton Clark, President (to serve one year).

James M. Dodge, Vice-President (to serve three years).

Cyrus Borgner, Treasurer (to serve one year).

Charles Day, Alfred W. Gibbs, J. J. Gibson, George R. Henderson, George A. Hoadley, Isaac Norris, Jr., Lawrence T. Paul, James S. Rogers, Managers (to serve three years).

The Chairman presented the President's statement of the work of the Institute for the fiscal year ending September 30, 1914. (Appended.)

Following the business meeting of the Institute, a joint meeting was held with the Philadelphia Section of the American Institute of Electrical Engineers, and Mr. H. F. Sanville took the chair with Dr. Dodge.

Mr. William S. Murray, Consulting Engineer, New York, New Haven, and Hartford Railroad, Hartford, Conn., was introduced and presented an interesting communication, entitled "Conditions Affecting the Success of Main Line Electrification," in which he gave a general exposition of his experiences in connection with the construction and operation of the electrified portion of the New York, New Haven, and Hartford Railroad. He drew from this the significant factors determining the success of heavy trunk line electrification, and pointed out how these factors could be generally applied.

The paper was discussed by several members present, after which a rising vote of thanks was accorded the speaker.

Adjourned.

R. B. OWENS,
Secretary.

PRESIDENT'S REPORT AND REPORTS OF THE COMMITTEES OF THE INSTITUTE AND THE COMMITTEES OF ITS BOARD OF MANAGERS

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1914.

To the Members of The Franklin Institute:

Your Board of Managers, in addition to inviting a close study of the reports of the several committees covering the activities of the Institute during the year ending September 30, 1914, and presented herewith, earnestly call your attention to several matters of the first importance to the Institute, and to that progress in mechanic arts which it is the Institute's function to promote.

Previous reports of the Board have kept you concurrently familiar with the continuing satisfactory progress of the general work of the Institute. Our membership has recently been greatly enlarged; the attendance at our lectures frequently taxes the seating capacity of our Hall; through the JOURNAL OF THE INSTITUTE our membership and the scientific world generally are promptly and authoritatively informed of the results of the latest researches in physical science and the most recent achievements of the engineering professions; the year's additions to the Library are more than usual; the work of our Science and Arts Committee has, as always, been marked by devotion and efficiency; the usefulness of our School of Mechanic Arts, notable for nearly ninety years, has never been greater than at present. These facts, while offering gratifying proof of the continuing usefulness of our Institute, should not satisfy us, in view of the opportunities for greater service which, as we believe, the near future offers.

As you are aware, the Institute owns a site upon the Parkway, perfectly located, and entirely sufficient for such new building or buildings as will best serve to enable it to meet these opportunities. Four years ago the Institute's income would not have been sufficient to maintain a modern adequate structure and to carry on therein, in the fullest degree, the work formulated in its charter. After this year, however, in the event of the friends of the Institute meeting the conditions of the Wahl bequest, the Institute will possess such an annual income as would justify it in so occupying a modern building as to greatly increase the extent and value of its services in the special field of its efforts. This building, on the south side of Logan Square, at the corner of Nineteenth and Race Streets, when erected, will have for its neighbors, as you know, the Cathedral, the Wills Hospital, the Academy of Natural Sciences, and the great and noble new Public Library. The building thus worthily located will face Logan Square and have a frontage of 110 feet and a depth of 130 feet. The entrance will be on Race Street, and the façade, while simple, will be dignified and in keeping with the purposes of the structure and with its location. The ground floor will be devoted mainly to laboratories, notably a thoroughly-equipped testing laboratory for the use of the Committee on Science and the Arts. On the first floor will be located the main Lecture Hall, fitted with every modern appliance for lecture demonstration and experiment, with a large members' room, apparatus and model rooms, offices and preparation rooms. The second floor will contain well-equipped lecture rooms for the use of such scientific and technical societies as may wish to use them, together with a number of office rooms and a Board room. The third floor will be occupied by the School, and the fourth floor will be devoted entirely to the Library.

We have only about one-third of the money necessary for such a building as we desire to erect; we own, however, what we believe to be the building site best located for the purposes of the Institute, and we believe that our annual income within a year or two will warrant the Institute in occupying such a building should the funds necessary for its erection be obtained. We therefore particularly urge, first, that the members and friends of the Institute see to it that the conditions of the Wahl bequest be promptly met; and, second, that the necessary money for the completion of the building fund, approximately half a million dollars, be obtained through private contribution or public grant: all this, that the work of the Institute may result in increased benefit to the citizen and to the State.

Recalling that the Institute's success in its efforts to promote the mechanic arts depends upon the degree of intelligence and devotion exercised in the committee rooms and in the office of the Secretary, your attention is again invited to the Board's and Institute's Committee reports and to our latest Year Book, as evidence adequate, though not comprehensive, of the ability of our Institute to-day to call to its service devotion and intelligence of the highest order.

Respectfully submitted,

FOR THE BOARD OF MANAGERS,

WALTON CLARK,
President.

PHILADELPHIA, January 20, 1915.

REPORT OF THE COMMITTEE ON LIBRARY

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1914.

To the President and Members of The Franklin Institute:

During the year there were expended $910.26 for the purchase of 306 volumes, 1 pamphlet, and 3 maps; $1575.92 for subscriptions to periodicals; $750.35 for binding 328 volumes; $4267.86 for salaries and expenses. There were available for meeting these expenditures $6650, appropriated by the Board of Managers, and $1271.10, being the income from the several Library funds.

The accessions by gift, exchange, and from the JOURNAL totalled 1192 volumes, 955 pamphlets, 3 maps, and 1 drawing.

The additions include many valuable works. More books have been purchased than in the previous year, and the falling off in the total additions is due only to a decrease in the accessions of pamphlets. Much valuable and interesting material has been secured by continuing the practice of applying to engineering firms and industrial establishments for their publications.

Three hundred and eleven pamphlets on mechanical subjects, most of them accessions of the current year, were classified, indexed separately, and bound into thirty-three volumes, and now form a part of the mechanical section. The work of classifying the pamphlets still stored was begun, but the progress is somewhat slow. The electrical and chemical pamphlets are being sorted out for indexing and binding.

Library Bulletin No. 3, being the second list of additions to the Library, was compiled and issued in September, and was also published in the JOURNAL.

On September 30, 1914, the Library contained 65,437 volumes. 48,955 pamphlets, 2279 maps and charts, and 1336 photographs.

The work of recording the status of the current periodical sets has been continued throughout the year and is progressing favorably. As this work proceeds, efforts are made to obtain missing volumes or parts of sets. The purchase of a dozen volumes completed the file of an important chemical journal published in Germany.

The subscription list was revised, but it was found that only three publications could well be discontinued.

In the binding of books and current periodicals as satisfactory progress has been made as possible, but, as pointed out in previous reports of this Committee, the requirement of a special fund to permit of a greater expansion of this work still exists.

The Committee held ten stated meetings during the year, at which many valuable suggestions were made and considered. At a recent meeting attention was called to the desirability of systematically going over each of the various subjects and departments with the view of ascertaining which of these were lacking in completeness, and on which the money available could be most profitably expended by the acquisition of recent works. It is only by the adoption of such a plan that the branches of the Library can each be maintained at its proper standard.

By removing about 4500 volumes to the overflow stack in the basement, space for recent acquisitions was secured.

There was a very gratifying increase in the attendance, especially on the evenings on which the Library was open until 10.00 P.M.

Appended hereto is a detailed statement of the operation of the Library during the year.

Respectfully submitted,

CLARENCE A. HALL,
Chairman.

PHILADELPHIA, January 13, 1915.

APPENDIX.

The following additions were made to the Library during the twelve months ending September 30, 1914:

SOURCE	Bd. Vols.	Unbd. Vols.	Pphs.	Maps	Drawing
Gift	591	535	913	3	
Exchange account	1				
JOURNAL	16	49	42		1
Binding new volumes:					
Institute appropriation	328				
Chemical Periodical Binding Fund	26				
Moore Fund	1				
Morris Fund	33				
Purchase:					
Institute appropriation	16	4		1	
Lea Fund	55	12	1		
Memorial Library Fund	1	2			
Moore Fund	166	16		2	
Morris Fund	33				
Potts Fund	1				
	1268	618	956	6	1

Total additions for the year 2849

Gifts of books, pamphlets, and periodicals in large quantities or of special value were received as follows:

Mr. H. M. B. Bary, copies of recent trade publications.

Booth, Garrett & Blair, volumes and pamphlets on mining and metallurgy.

Crocker-Wheeler Company, Philadelphia, Pa., electrical publications.

Electric Storage Battery Company, engineering and trade publications.

Mr. Guy H. Elmore, pamphlets and copies of society publications.

The Engineers' Club, engineering publications and Society Transactions of 1913.

Mr. Spencer Fullerton, several lots of pamphlets and magazines on various subjects.

Mr. F. Lynwood Garrison, magazines on mining and metallurgy.

The General Electric Company, copies of its publications.

Mr. J. J. Gibson, historic electrical pamphlets.

Mr. Clarence A. Hall, books, pamphlets, and maps on chemistry and metallurgy.

Dr. Carl Hering, books, pamphlets, and magazines on electrical and other subjects.

Miss Houston, electrical magazines.

Mr. Louis E. Levy, publications on photography and printing.

Mr. R. Louis Lloyd, set of publications of the Illuminating Engineering Society.

Dr. Caspar W. Miller, volumes of magazines on automobiles and horseless vehicles.

Philadelphia Book Company, books, pamphlets, and maps on various subjects.

Mr. Harrison Souder, engineering publications.

Spreckels' Sugar Refinery, volumes of the Official Gazette of the U. S. Patent Office.

Mr. Harrison D. Stratton, pamphlets on refrigeration.

Miss Wood, books on various subjects.

The executors of the estate of Mrs. W. H. Wahl, books, pamphlets, and maps from the library of the late William H. Wahl.

The U. S. Bureau of Standards, publications.

Mr. Joseph A. Arnold, Editor and Chief, Division of Publications, U. S. Department of Agriculture, has supplied the Library with copies of the current publications of the Department, and the Committee is indebted to him for the continuance of this courtesy.

DUPLICATES.

A number of duplicates have been received during the year from various sources, and the total stock at this time is 678 volumes. These will be used for exchange purposes, and the material so received will be added to the Library.

BINDING.

The total work done in the bindery was as follows:

	Bound	Rebound
Recent volumes of periodicals	328	
Recent volumes of periodicals charged to Chemical Periodical Binding Fund	26	
Old volumes	63	27
Books purchased with the income of the Moore Fund	4	1
Morris Fund	35	
Potts Fund	1	
	457	28

Total number of volumes 485

REPORT OF THE COMMITTEE ON MUSEUMS

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1914.

To the President and Members of The Franklin Institute:

The Committee on Museums begs to report progress for the year ended September 30, 1914.

The following gifts have been received during the year and have been placed in charge of the Committee:

> Model of J. P. Ross's Improved Reciprocating Engine, Lewisburg, Pa. Original adapted to blast furnaces and water works. Patented January 22, 1856. Model to scale of three-fourths inch to one foot. Gift of James C. Wobensmith, Esq.
>
> Phantoscope, a motion-picture projecting machine, designed particularly for home use. Gift of Mr. C. Francis Jenkins, inventor.

Atwater Kent Ignition System, a system of battery ignition for automobile engines. Model consists of "Unisparker," distributer and spark-plugs mounted on stand. Gift of Mr. A. Atwater Kent, inventor.

Bronze Bust of Matthias W. Baldwin, manager of the Institute, 1827–1854; vice-president, 1855–1863. Bust modelled by Herbert Adams, New York, 1904, and cast by Aubry Brothers, New York; mounted on carved marble pedestal. Bequest of Mr. Francis T. Sully Darley.

Walnut Secretary Bookcase and Rug. Gifts of Miss Mary Thorn.

Several models have been received since the ending of the period this report covers, and mention of these will be included in the next report.

Respectfully submitted,

ALEX. E. OUTERBRIDGE, JR.,
Chairman.

PHILADELPHIA, January 13, 1915.

REPORT OF THE COMMITTEE ON MEETINGS

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1914.

To the President and Members of The Franklin Institute:

During the year ending September 30, 1914, eight stated meetings were held.

At the May meeting the Elliott Cresson Medal was presented to Dr. Edgar F. Smith and to Dr. Orville Wright, two of the four scientists to whom this medal was awarded for distinguished achievement, the other two being Dr. Karl Ritter von Linde and Professor Dr. Josef Maria Eder. The presentations were made by President Walton Clark, and were followed by addresses from Dr. Smith and Dr. Wright.

Under arrangements made by your Committee, with the coöperation of the Secretary's office, papers were presented during the year as follows:

October 15, 1913.

"The Revolving Cylinder Internal Combustion Motor." Emile Berliner, Washington, D. C.

November 19, 1913.

"Producer Gas from Low-grade Fuels." R. H. Fernald, M.E., Ph.D., Consulting Engineer, U. S. Bureau of Mines; Whitney Professor of Dynamical Engineering, University of Pennsylvania, Philadelphia, Pa.

December 17, 1913.

"Petroleum and Its Derivatives." David T. Day, Ph.D., Department of the Interior, U. S. Geological Survey, Washington, D. C.

January 21, 1914.

"The Heat Received by the Earth from Stars and Planets." Ernest F. Nichols, Sc.D., LL.D., President, Dartmouth College, Hanover, N. H.

February 18, 1914.

"Artificial Daylight." Herbert E. Ives, Ph.D., Photometrical Laboratory, The United Gas Improvement Company, Philadelphia, Pa.

March 18, 1914.

"Marine Applications of Electricity." H. A. Hornor, B.A., New York Shipbuilding Company, Camden, N. J.

April 15, 1914.

"Researches in Metallurgy of Iron." A. S. Cushman, Ph.D., Director, Institute of Industrial Research, Washington, D. C.

May 20, 1914.

"Scientists from the Keystone State." Edgar F. Smith, Ph.D., Sc.D., LL.D., Provost, University of Pennsylvania, Philadelphia, Pa.

"Stability of Aëroplanes." Orville Wright, B.S., LL.D., Dayton, Ohio.

The above papers were referred to the Committee on Publications, and were afterwards, with the exception of one, published in the Journal.

Dr. E. F. Northrup, Palmer Physical Laboratory, Princeton, N. J., was scheduled to address the stated meeting in March, but was unexpectedly unable to do so.

James S. Rogers,
Philadelphia, January 13, 1915. *Chairman.*

REPORT OF THE COMMITTEE ON INSTRUCTION

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1914.

To the Board of Managers:

The courses offered in the ninetieth year of the Institute's School of Mechanic Arts, commencing in September, 1913, were substantially the same as those given in the preceding year, and the division of the instructional work into the four Departments of Drawing, Mathematics, Mechanics, and Naval Architecture was maintained.

The School opened on September 15, 1913, and during the year three hundred and twenty students were enrolled. This represented an increase of twenty over the preceding year and was the highest enrolment since the discontinuance of the Institute's Branch School at Germantown Junction in 1899. The largest classes formed were those in first-year Mechanical Drawing, in which eighty-nine students were enrolled, and in first-year Mathematics, to which fifty-eight students were admitted.

The faculty for the year was as follows:

Professor William H. Thorne, Director of the School, and in charge of the Department of Drawing.

Professor William E. Bullock, Assistant Director, and in charge of the Department of Mechanics.

Professor H. P. Tyson, in charge of the Department of Mathematics.

Professor H. C. Towle, in charge of the Department of Naval Architecture.

Professor Thorne was assisted in his Department by Professor Clement Remington, in charge of Architectural and Freehand Drawing, and by Messrs. F. H. Lobb, I. P. Pedrick, C. Rommel, and W. W. Twining, instructing in Mechanical Drawing.

Mr. W. A. Van Osten assisted in the Department of Mathematics, and Messrs. E. Bark and John F. Allison in Mechanics.

On November 15, 1913, Miss Mary Thorn, of Philadelphia, donated to the Institute a sum of money, the interest on which is to be used to provide free scholarships in the Departments of Mathematics, Mechanics, and Naval Architecture. By means of this gift, and also with the interest from the B. H. Bartol Fund, your Committee is now able to award free scholarships in all four Departments of the School.

During the season seven visits to manufacturing concerns were paid by students of the School, as follows:

Philadelphia Rapid Transit Company, Thirty-third and Market Streets Station, Philadelphia, Pa.
The Autocar Company, Ardmore, Pa.
The Commercial Museum, Philadelphia, Pa.
Hess-Bright Manufacturing Company, Philadelphia, Pa.
The Philadelphia Electric Company, Twenty-eighth and Christian Streets, Philadelphia, Pa.
United Gas Improvement Company, Experimental Department and Photometrical Laboratory, Philadelphia, Pa.
Bureau of Water, Torresdale Pumping Station, Philadelphia, Pa.

In every case the attendance was good and much interest was shown by those present. Our thanks are due to the managements represented for their courtesy.

A lecture, entitled "In Navajo Land," was delivered in the Hall of the Institute, by Mr. Frederick Monsen, F.R.G.S., on January 16, 1914, under the auspices of the Alumni Association. About two hundred students and friends were in attendance.

The attendance in the School throughout the year was well up to the average, and the work done was of exceptional merit in a large number of individual cases.

The graduating exercises were held in the Hall of the Institute on the evening of April 17, 1914. Dr. Walton Clark, President of the Institute, occupied the chair, and the graduating address was delivered by Dr. Gellert C. Alleman, Professor of Chemistry, Swarthmore College, Swarthmore, Pa. The Alumni Association was represented by Mr. J. C. Wobensmith. The annual report of the work of the School was presented by Professor Thorne. Forty-six students were graduated, seventeen in Mechanical Drawing, five in Architectural Drawing, two in Freehand Drawing, ten in Mathematics, six in Mechanics, and six in Naval Architecture. Twelve students in the Department of Drawing were the recipients of scholarships from the B. H. Bartol Fund, entitling them to free instruction. Six students were awarded free scholarships from the Isaac B. Thorn Fund. The student of greatest merit in the

Department of Mathematics was awarded a prize donated by Mr. J. B. McCall, President of The Philadelphia Electric Company. The student of greatest merit in the Department of Mechanics was also given a prize donated by Mr. Wilfred Lewis, President of the Tabor Manufacturing Company. A set of drawing instruments, offered by the New York Shipbuilding Company, was awarded to the student of greatest merit in the Department of Naval Architecture. Six graduates received awards provided by the Alumni Association of The Franklin Institute, and sixteen graduates making a perfect attendance record were awarded free membership for one year in the Association. In the Winter Term, thirty-nine students were awarded certificates of Honorable Mention; forty-four students received similar certificates in the Spring Term.

The graduates were invited to the annual smoker and luncheon of the Alumni Association, held on the evening following the exercises. At the luncheon ninety-eight covers were laid, and speeches were made by Dr. Walton Clark, Mr. George R. Henderson, and others.

In the summer of 1914, in preparation for the ninety-first year, a new School Calendar was issued. An attractive programme of visits to places of engineering interest for the new year was prepared. Valuable prizes were donated by Mr. J. B. McCall, Mr. Wilfred Lewis, the Alumni Association of The Franklin Institute, and the New York Shipbuilding Company, as in previous years, and by Mr. S. M. Vauclain, The Baldwin Locomotive Works, and Mr. W. D. Baldwin, The Otis Elevator Company, in addition. Announcements of these items were included in the Calendar.

In August, 1914, Hon. G. W. Edmonds, member of the Institute, offered to pay the tuition fees of five new scholars as an inducement to young men to enter the School. Mr. Edmonds's offer was accepted by the Committee, and an examination of young men was held and five scholars selected. Three of these are now studying in the Department of Drawing, one in Mathematics, and one in Mechanics.

The Committee on Instruction desires to express its appreciation to the individual members of the faculty for their earnest endeavor in their work, and wishes to congratulate them on the excellent results secured. The registration figures for the year, as well as for the previous year for comparison, follow:

	1912–13		1913–14	
	Winter Term, Sept.–Dec.	Spring Term, Jan.–Apr.	Winter Term, Sept.–Dec.	Spring Term, Jan.–Apr.
Drawing	158	132	188	148
Mathematics	61	39	71	57
Mechanics	38	23	30	20
Naval Architecture	29	23	17	15
	286	217	306	240

Respectfully submitted,

LAWRENCE T. PAUL,
Chairman.

PHILADELPHIA, January 13, 1915.

REPORT OF THE COMMITTEE ON ELECTIONS AND RESIGNATIONS OF MEMBERS

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1914.

To the Board of Managers:

During the fiscal year ending September 30, 1914, there were one hundred and eleven members enrolled; resignations were received and accepted from thirty-one members; and deaths were recorded of twenty-six members.

The figures for the several classes of membership and for the two preceding years follow:

ELECTIONS:	1911–12	1912–13	1913–14
Resident Members	68	101	47
Non-Resident Members	33	186	57
Associate Members	7	1	7
Honorary Members	1	0	0
Life Members	1	3	0
	110	291	111
RESIGNATIONS:			
Resident Members	27	16	17
Non-Resident Members	13	13	12
Associate Members	1	2	2
	41	31	31
DEATHS:			
Resident Members	9	8	6
Non-Resident Members	4	4	4
Life Members	11	6	14
Honorary Members	1	1	2
Associate Members	1	0	0
	26	19	26

SUMMARY:		1913–14
Total Elections		111
Total Resignations	31	
Total Deaths	26	
		57
Net increase in membership		54

Respectfully submitted,

W. C. L. EGLIN,
Chairman.

PHILADELPHIA, January 13, 1915.

REPORT OF THE COMMITTEE ON STOCKS AND FINANCE

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1914.

Property and Funds.

Building and land, 13–17 South Seventh Street	$60,000.00	
Library	100,000.00	$160,000.00

	Principal	Unexpended Income	
Funds held by Board of Trustees	$280,843.37	$781.65	
Funds held by Board of Managers	23,481.65	56.69	
Franklin Institute Building Fund	363,924.31	......	
Elliott Cresson Medal Fund	3,000.00	21.35 (overdrawn)	
Franklin Fund and Building Committee	4,395.43	......	
Total funds	$675,644.76	$816.99	676,461.75
Grand total			$836,461.75

Liabilities.

Certificates of stock	$30,370.00
Mortgage on Institute Building (held by Trustees as investment for funds)	30,575.00
Bills payable	20,250.00
Accounts payable	3,929.50
Unearned income	1,159.75
Grand total	$86,284.25

Income and Expenses Applicable to Year Ending September 30.

Income.

Dues		$11,048.17
Initiation fees		295.00
General Endowment Fund		9,388.90
James H. Cresson Memorial Fund		2,268.23
John Scott Medal Fund		375.00
Estate of John Turner		158.97
Estate of Robert Wright		1,615.55
Instruction: Drawing	$1,651.50	
Mathematics	629.50	
Mechanics	251.50	
Naval Architecture	213.50	2,746.00
Publications: Subscriptions and sales	$2,002.13	
Advertising	2,617.65	4,619.78
Total		$32,515.60

Expenses.

Building:	Wages	$1,212.75	
	Repairs and maintenance	421.71	
	Taxes, water rent, and insurance	409.27	
	Heat, light, and power	784.80	
	Miscellaneous supplies and expense	249.35	$3,077.98
Elections and resignations			143.69
Instruction:	Drawing	$1,321.20	
	Mathematics	302.50	
	Mechanics	277.04	
	Naval Architecture	220.00	
	Miscellaneous expense	870.30	
	Popular lectures	76.98	3,068.02
Library:	Salaries	$4,028.45	
	Books and periodicals	1,575.92	
	Binding	750.35	
	Miscellaneous expense	239.41	6,594.13
Meetings			444.06
Office and General:	Salaries	$8,770.32	
	Office expense	816.09	
	General expenses	1,176.03	10,762.44
Publications:	Printing	$6,077.21	
	Reprints	829.35	
	Illustrating	710.96	
	Miscellaneous expense	611.79	
	Year-Book	450.00	8,679.31
Science and Arts			1,623.78
Sections			1,128.49
Basement renovation			372.95
Fire protection improvements			1,666.22
Interest and discount			1,394.34
Membership badges			84.68
Miscellaneous income and expense			469.25
Total			$39,509.34
Deficit			6,993.74

During the fiscal year there has been an increase in funds as follows:

General Endowment Fund	$10,300.00
Elizabeth M. Graff Fund	14.90
Franklin Medal Fund *	5,000.00
Isaac B. Thorn Scholarship Fund *	1,000.00
Franklin Institute Building Fund	7,260.85†

The mortgage on the Institute building has been increased by $9250. Bills payable have been decreased by $2000.

Respectfully submitted,

WALTON FORSTALL,
Chairman.

PHILADELPHIA, January 13, 1915.

REPORT OF THE COMMITTEE ON PUBLICATIONS

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1914.

To the Board of Managers:

The policy recently adopted by the Committee on Publications and duly sanctioned by the Board, directed to the purpose of making the publications of the Institute adequately expressive of its scope and activities, has been consistently pursued during the past year. The JOURNAL OF THE INSTITUTE, particularly, as its recognized exponent, has accordingly been developed as fully as conditions would permit, and the Committee has given all possible support to the efforts of the editor and of our editorial collaborators in this direction. The transactions of the Institute, of its various Sections and of its Committee on Science and the Arts, published from month to month in the JOURNAL, have continued to be supplemented by the series of important communications, inaugurated last year, from the U. S. Bureau of Standards, and by a number of very valuable papers from our associate editors. To the list of these latter has been added during the past year the name of our esteemed fellow-member of the Institute, Professor Gaetano Lanza, of the engineering department of The Baldwin Locomotive Works. The very welcome service rendered to the Institute by the distinguished authorities who are giving us their coöperation in the editorial conduct of the JOURNAL is gratefully acknowledged by your Committee.

The distinctions provided in recognition of especially important papers published in the JOURNAL during the year 1913 were awarded to their respective authors by the Committee on Science and the Arts at its May stated meeting. Details of these awards are included in the report of that Committee.

The Year-Book of the Institute, in its improved form and thoroughly revised, was duly published in October, and has been appreciatively received by the membership.

The cost of the work carried on by the Committee in the fiscal year ending September 30, *ultimo,* was $8679.31, of which $7617.52 appertains to the

---

* New funds.

† Decrease, due to loss on securities sold to purchase site.

JOURNAL, $450 to the Year-Book, and $611.79 to extraneous expenses. The income from the JOURNAL through subscriptions, sales, and advertising accounts was $4619.78, leaving a debit balance of $4059.53. Inasmuch as the JOURNAL and Year-Book are furnished to all members of the Institute as among the privileges of membership, a fair proportion of the membership dues may properly be credited to the item of publication, in which case the account would be practically balanced.

Respectfully submitted,

LOUIS E. LEVY,
Chairman.

PHILADELPHIA, January 13, 1915.

REPORT OF THE COMMITTEE ON EXHIBITIONS

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1914.

To the Board of Managers of The Franklin Institute:

There have been no developments since the last report of the Committee which would encourage the expectation of an exposition in the near future, except in the fact that a temporary building and annexes have been permitted on the Parkway near Vine Street. This indicates that similar facilities may be secured by the Institute, as suggested in the last report. It is questionable whether the present structure would be suited for exposition purposes, for it is primarily an auditorium.

One exposition in southern California has opened for the year, and the one at San Francisco will soon be in operation, and until these are accomplished facts and the character of the exhibits known the desirability of having some of them on display in Philadelphia subsequently to the other exhibitions need not be considered.

Therefore your Committee would report progress.

JOHN BIRKINBINE,
Chairman.

PHILADELPHIA, January 13, 1915.

REPORT OF THE COMMITTEE ON SECTIONAL ARRANGEMENTS

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1914.

To the Board of Managers:

The Committee on Sectional Arrangements takes pleasure in reporting that nineteen lectures were delivered during the year ending September 30, 1914, as follows:

PHYSICS AND CHEMISTRY SECTION—*Six Meetings.*

November 6, 1913.

"The Present State of our Knowledge of Solution." Harry C. Jones, Ph.D., Professor of Physical Chemistry, Johns Hopkins University, Baltimore, Md.

November 13, 1913.

"High Pressures and Five Kinds of Ice." P. W. Bridgman, A.M., Jefferson Physical Laboratory, Harvard University, Cambridge, Mass.

January 8, 1914.

"Physics of the Sun—A Review of Recent Solar Research." C. G. Abbott, S.M., Smithsonian Institution, Washington, D. C.

January 29, 1914.

"Advantages and Disadvantages of Water Storage." W. P. Mason, C.E., M.D., LL.D., Professor of Chemistry, Rensselaer Polytechnic Institute, Troy, N. Y.

February 11, 1914.

"The Biochemistry of Soil Fertility." Oswald Schreiner, Ph.D., U. S. Department of Agriculture, Washington, D. C.

March 5, 1914.

"By-products of Coal." L. C. Jones, Ph.D., The Solvay Process Company, Syracuse, N. Y.

ELECTRICAL SECTION—*Four Meetings.*

October 2, 1913.

"Effect of Electrical Engineering on Modern Industry." Charles P. Steinmetz, Ph.D., Electrical Engineer, General Electric Company, and Professor of Electrical Engineering, Union College, Schenectady, N. Y.

October 23, 1913.

"High-voltage Engineering." F. W. Peek, Jr., Consulting Engineer, General Electric Company, Schenectady, N. Y.

April 9, 1914.

"Recent Developments in the Art of Illumination." Preston S. Millar, Electrical Testing Laboratories, New York City.

April 23, 1914.

"Recent Developments in Hyperbolic Functions as Applied in Electrical Engineering." A. E. Kennelly, Sc.D., Professor of Electrical Engineering, Harvard University, Cambridge, Mass.

MECHANICAL AND ENGINEERING SECTION—*Seven Meetings.*

November 25, 1913.

"Recent Developments in Aëromechanics." A. F. Zahm, M.E., Ph.D., Washington, D. C. (Joint meeting with the Aëro Club of Pennsylvania.)

December 11, 1913.

"The Catskill Water Supply for New York City." J. Waldo Smith, C.E., Chief Engineer, Board of Water Supply, New York City.

January 15, 1914.

"Sewage Treatment." Rudolph Hering, Consulting Engineer and Sanitary Expert, New York City.

February 26, 1914.

"The Valuation of Public Utility Properties." M. E. Cooley, D.Eng., LL.D., Dean of the Department of Engineering, University of Michigan, Ann Arbor, Mich.

March 26, 1914.

"Recent Progress in Military Aëronautics." Col. Samuel Reber, U. S. A., New York City. (Joint meeting with the Aëro Club of Pennsylvania.)

April 2, 1914.

"Some Engineering Problems in Sanitary Science." J. A. Vogleson, Chief of the Bureau of Health, City of Philadelphia.

April 30, 1914.

"Locomotive Superheaters and Their Performance." C. D. Young, Engineer of Tests, Pennsylvania Railroad, Altoona, Pa. (Joint meeting with the American Society of Mechanical Engineers.)

MINING AND METALLURGICAL SECTION—*Two Meetings.*

October 30, 1913.

"The Making of Sound Steel Ingots." Bradley Stoughton, Ph.B., Consulting Metallurgical Engineer, New York City.

December 4, 1913.

"Some Present-day Metallurgical Processes." D. A. Lyon, A.M., Pittsburgh, Pa., Representative in United States, Canada, and Mexico of Electro-Metals, Ltd., London, England. (Joint meeting with the American Institute of Electrical Engineers.)

SECTION OF PHOTOGRAPHY AND MICROSCOPY—*No Meetings.*

It will be noted that four joint meetings were held, one with the American Society of Mechanical Engineers, one with the American Institute of Electrical Engineers, and two with the Aëro Club of Pennsylvania.

The attendance at meetings shows a gratifying increase, the average being about 170 for the period covered by this report.

The lectures were all illustrated by lantern slides, and in many instances special apparatus and exhibits were introduced. Most of these lectures were published in the JOURNAL.

CHARLES DAY,
Chairman.

PHILADELPHIA, January 13, 1915.

REPORT OF THE COMMITTEE ON ENDOWMENT

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1914.

To the Board of Managers:

The subscriptions to meet the conditions of the Wahl bequest to The Franklin Institute to date are as follows:

Promises to subscribe	$15,795.00
Cash on deposit at the Girard Trust Co.	485.00
Total	$16,280.00

Some determined effort must shortly be made to secure the balance of the amount necessary to meet the conditions of the Wahl bequest, and, as the suggestion was made in Dr. Wahl's will that any subscription by an individual, the City of Philadelphia, or the State of Pennsylvania, would meet the requirements, your Committee proposes that a bill be introduced at the next meeting of the State Legislature appropriating a certain amount for the use of The Franklin Institute.

It is the opinion of the Committee that each member of the Institute should make himself a Committee of One to secure subscriptions during the next year to the Wahl Fund, whether the subscriptions are large or small.

As set by Dr. Wahl's will, the time limit for securing these subscriptions will expire December 16, 1916.

During the year 1914 the Institute received Ten Thousand Dollars ($10,000) from the executors of the estate of Anna Blanchard, deceased, and also received notice that it is one of the residuary legatees of the estate of the late Miss Elizabeth S. Shippen.

In connection with the John Scott Medal Fund, the Board of City Trusts has appropriated an allowance of Nine Hundred Dollars ($900) annually for expenses.

Respectfully,

HENRY HOWSON,
Chairman.

PHILADELPHIA, January 13, 1915.

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1914.

To the President and Members of The Franklin Institute:

Your Committee on Science and the Arts investigated and disposed of forty-two cases during the year.

Ten stated meetings were held, as provided for in the Regulations. The average attendance was 23.4, or fifty per cent. above the quorum necessary for all actions on reports. At no meetings were there less than twenty members present.

At the April meeting the Secretary announced that Mr. Samuel Insull, of Chicago, Ill., had founded The Franklin Medal Fund, that his gift had been accepted by the Board of Managers of the Institute, and that the following deed had been duly executed and delivered:

> KNOW ALL MEN BY THESE PRESENTS, That The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, hereinafter named The Franklin Institute, for and in consideration of the sum of Six Thousand Dollars ($6000) to it in hand paid by Samuel Insull, Esq., the receipt whereof is hereby acknowledged, does hereby certify and declare that it holds and will use said sum of money for the following uses, intents, and purposes, and upon the following perpetual trusts, that is to say:

1. To expend One Thousand Dollars ($1000), or so much thereof as may be necessary, for the purpose of paying for the design of a medal, and the necessary dies and diploma plates for the purposes hereinafter set forth.

2. To invest and keep invested the balance of said sum, and from the income derived from such investments from time to time to strike off and award medals from said design to workers in physical science or technology, without regard to country, whose efforts, in the opinion of the Board of Managers of said The Franklin Institute, have done most to advance our knowledge of physical science or its application. Should the income derived from this fund be more than necessary for the purposes aforesaid, the said The Franklin Institute may, in its discretion, award so much of the surplus as its Board of Managers deems wise, as premiums to accompany said medals.

3. The fund thus set apart shall be known as "The Franklin Medal Fund" (founded January 1, 1914, by Samuel Insull, Esq.).

4. The medals to be awarded as aforesaid shall be of gold, shall have distinct artistic merit, shall be of the intrinsic value of about Seventy-five Dollars ($75), and shall have on one side thereof a medallion of Benjamin Franklin taken from his portrait by Thomas Sully, now in the possession of the said The Franklin Institute.

IN WITNESS WHEREOF, The said The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts has hereunto set its common or corporate seal, attested by the signatures of its President and Secretary, this 28th day of March, A.D. 1914.

WALTON CLARK,
President.

[SEAL]

R. B. OWENS,
Secretary.

A sub-committee was appointed to draw up the necessary amendments to the Regulations. This sub-committee reported at the June meeting, and its report, recommending the appointment each year of a sub-committee to make recommendations for awarding this medal, was adopted at the September meeting.

At the February meeting resolutions were framed petitioning the Board of Directors of City Trusts of the City of Philadelphia for further financial assistance to meet the costs of investigating applications for the John Scott Medal. These resolutions were communicated to the Board of Directors of City Trusts, and the latter gave consideration to them and adopted the following resolution at its May meeting:

> RESOLVED, That The Franklin Institute be paid the sum of Nine Hundred Dollars ($900) per annum, from May 1, 1914, to reimburse it for expenses incurred in the investigation and applications for medals from the John Scott Medal Fund.

The resignation of Professor Haupt was received at the February meeting with regret. A sub-committee was appointed which drafted resolutions expressing the sentiments of the Committee. These resolutions were engrossed and presented to Professor Haupt, and a copy of them was published in the April issue of the JOURNAL.

Amendments to the Regulations proposed by Mr. L. E. Levy and Mr. H. F. Colvin were considered and adopted in their final form.

The Regulations incorporating all the amendments as above were included in the 1914 Year-Book of the Institute, published in October.

In accordance with the recommendation of the former chairman of this Committee, Mr. Crisfield, an amendment replacing the Sub-committee on New Subjects and Publicity and the Sub-committee on Preliminary Examination by a Sub-committee to be known as the Sub-committee on New Subjects and Preliminary Examination, was adopted at the March meeting. This sub-committee has since held one meeting before each stated meeting. During the year it received eleven applications and considered twenty-five subjects, five of which were recommended for investigation.

Appended to this report is a detailed statement of the operation of the Committee for the year. The number of awards recommended by standing sub-committees and sub-committees of investigation as the result of their labors is indicated below:

SUB-COMMITTEE ON LITERATURE.

Number of Potts Medals recommended	1
Number of Longstreth Medals recommended	3

SUB-COMMITTEE ON ELLIOTT CRESSON AWARDS TO DISTINGUISHED SCIENTISTS AND TECHNOLOGISTS.

Number of awards recommended	4

SUB-COMMITTEES ON INVESTIGATIONS.

Number of awards recommended	17

A detailed list of the awards made during the year is also appended.

Your Committee has now adopted the practice, recommended also by the former chairman, of holding an informal dinner prior to each meeting. The average attendance at these functions was twelve members.

During the year medals awarded to inventors who were able to attend stated meetings of the Institute have been presented to them by the President.

In order to still further advance the usefulness of the work of this Committee, a recommendation made a year ago is reiterated as follows: That there should be some more widespread method of bringing before the public the Committee's facilities for reporting upon applications, and the fact stated that such investigations are made without charge. It is believed, in this connection, that the coöperation of other engineering, scientific, and educational bodies can be secured and our efforts to encourage inventive genius and original research made more effective. The Journal of the Institute alone cannot accomplish all that is desired in this direction.

It is also believed that the time is propitious for the Committee, acting in accordance with its power and on behalf of the Institute, to call attention to the facilities it possesses for reporting upon matters of public or semi-public interest. The records of the Committee contain many examples of the exercise of this function in the past, such as, for instance, its report upon the Standardization of Screw Threads, the Manayunk Intercepting Sewer, the Abatement of the Smoke Nuisance in Philadelphia, etc. The bringing of our facilities in this connection to the proper notice may probably best be accomplished by the appointment of a standing sub-committee to receive requests for, and to formulate, opinions upon questions of this character. The State and municipal departments, for example, would no doubt be glad to receive and acknowledge help of this kind. In this way the work of the Committee would be made of greater benefit to the community at large. In former times our public officers freely consulted the Institute upon matters in question, and in many cases the Committee was able to render services to them, an honor which was greatly appreciated by its members, and a pleasurable duty.

In conclusion, it should be stated that the work of the past year has been of great interest, not only in consideration of the subjects received, but also of the eminent and able men to whom awards have been made, and of the appreciation of our efforts by these recipients.

Respectfully submitted,

George R. Henderson,
Chairman.

Philadelphia, January 13, 1915.

APPENDIX.

Statement of the Committee's Operation
for the
Year Ended September 30, 1914.

CASES.

Cases pending, October 1, 1913		23
Applications during the year	26	
Special reports	9	
	—	35
		58
Disposed of during the year		42
Leaving pending		16

DISPOSITION OF CASES.

Elliott Cresson Awards	6
Howard N. Potts Awards	1
Edward Longstreth Awards	6
John Scott Legacy Recommendations	11
Certificates of Merit	1
	25

Awards Made during the Year.

THE ELLIOTT CRESSON MEDAL.

Josef Maria Eder, Ph.D., of Vienna, Austria, in recognition of his important original researches in the science of photochemistry and his many valuable contributions to the literature of that science and of the graphic arts.

Wolfgang Gaede, of Freiburg-in-Bresgau, Germany, for his Molecular Air Pump.

Peter Cooper Hewitt, Sc.D., of New York, N. Y., for his Mercury Arc Rectifier.

Professor Karl Ritter von Linde, Ph.D., of Munich, Germany, in recognition of his scientific investigations of the processes of refrigeration and the liquefaction of gases, and of his inventions of machinery for applying these processes in the manufacture of ice and for the purposes of cold storage.

Professor Edgar Fahs Smith, Ph.D., Sc.D., LL.D., of Philadelphia, Pa., in recognition of his leading work in the field of electrochemistry, of his many contributions to the literature of chemical science, and of his great service in university education.

Orville Wright, B.S., LL.D., of Dayton, Ohio, in recognition of the epoch-making work accomplished by him, at first together with his brother Wilbur and latterly alone, in establishing on a practical basis the science and art of aviation.

THE HOWARD N. POTTS MEDAL.

Ralph Modjeski, D.Eng., of Chicago, Ill., for his paper on "Design of Large Bridges, with Special Reference to the Quebec Bridge," in the September, 1913, issue of the Journal.

THE EDWARD LONGSTRETH MEDAL.

H. T. Herr, of Pittsburgh, Pa., for his paper on "Recent Developments in Steam Turbines," in the February, March, April, May, and June, 1913, issues of the Journal.

Hiram H. Hirsch, of Philadelphia, Pa., for his Electric Safety Lamp.

Wm. J. Humphreys, Ph.D., of Washington, D. C., for his paper on "Volcanic Dust and Other Factors in the Production of Climatic Changes, and Their Possible Relation to Ice Ages," in the March, 1913, issue of the Journal.

Kinkead Manufacturing Company, of Boston, Mass., for their Apparatus for Aligning and Levelling Shafting.

John M. Rusby, of Philadelphia, Pa., for his paper on "Industrial Combustible Gases," in the July, 1913, issue of the Journal.

Johann Stumpf, of Charlottenburg, Germany, for his Una-Flow Steam Engine.

THE CERTIFICATE OF MERIT.

Ellis B. Ridgway, of Coatesville, Pa., for his Steam Hydraulic Elevator.

THE JOHN SCOTT LEGACY MEDAL AND PREMIUM.

Charles S. Batdorf, of New York, N. Y., for his Coin Counting and Wrapping Machine.

Halcolm Ellis, of Newark, N. J., for his Adding-Typewriter.

C. E. Guillaume, Ph.D., of Sèvres, France, for his alloy Invar.

Aldus C. Higgins, of Worcester, Mass., for his Electric Furnace in which Alundum is made commercially.

Charles B. Jacobs, of New York, N. Y., for his Process of Producing a New Abrasive and Refractory Material.

C. Francis Jenkins, of Washington, D. C., for his Motion-picture Apparatus.

Jesse W. Reno, of New York, N. Y., for his Inclined Elevator or Escalator.

Allen A. Tirrill, of Pittsburgh, Pa., for his Automatic Potential Regulator.

Adolph Spielman, of Philadelphia, Pa., for his Cloth-cutting Machine.

JOHN SCOTT MEDAL RECOMMENDATIONS.

(*Awards pending, September 30, 1914.*)

A. Atwater Kent, of Rosemont, Pa., for his Unisparker.

Elmer A. Sperry, of New York, N. Y., for his Gyro-Compass.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, January 6, 1915.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 6, 1915.

MR. GEORGE R. HENDERSON *in the Chair.*

The following reports were presented for first reading:

No. 2620.—Adamite. Advisory. Adopted.
No. 2621.—Wahl Adding Machine.

The following report was presented for final action:

No. 2624.—Vanier's Potash Bulb. Certificate of Merit. Adopted.

R. B. OWENS,
Secretary.

AWARD OF THE JOHN SCOTT MEDAL.

The CITY OF PHILADELPHIA, acting on the recommendation of The Franklin Institute, has awarded the John Scott Legacy Medal and Premium to Charles Edouard Guillaume, of Sèvres, France, for his alloy Invar. This alloy contains approximately 63.8 per cent. iron and 36.2 per cent. nickel. It is characterized by possessing an extremely small coefficient of linear expansion, about 0.0000004 per degree Centigrade. Within the limits of atmospheric temperature change its expansion is very exactly proportional to the temperature. It has a modulus of elasticity of about two-thirds that of steel, and its hardness is greater than that of hard brass. Invar has found a wide application in metrology and in horology. In the former it is particularly useful for secondary standards of length, and in the latter it is employed for pendulum rods, compensating devices for torsion pendulums and balance wheels correcting the secondary error of temperature in chronometers.

AWARD OF THE CERTIFICATE OF MERIT.

MR. GEORGE P. VANIER, of Steelton, Pa., has been awarded a Certificate of Merit for his Potash Bulb. This bulb has been particularly designed for use in the determination, in industrial laboratories, of the total carbon in iron or steel. In such laboratories time is often a very important factor. The bulb is of large capacity, and, by the provision of a glass spiral in which the gases of combustion of the sample under test and the potash solution circulate together, a high rate of absorption of carbonic acid is obtained. With the bulb is combined a drying tube.

SECTIONS.

Mechanical and Engineering Section.—A meeting of the Section was held in the Hall of the Institute on Thursday, January 7, 1915, at 8 P.M. Mr. George R. Henderson presided. The minutes of the previous meeting were approved as published.

The Chairman introduced Mr. Wm. H. Connell, Chief, Bureau of Highways and Street Cleaning, City of Philadelphia, who presented a communication, entitled "The Organization, Character of Personnel, Scope of Work, and Methods of Operation and Control of a Large Municipal Highway Department." In his remarks the speaker considered the construction and maintenance of highways, the laying out of parks and parkways, street cleaning, collection of ashes, garbage and refuse, and the general work coming under the jurisdiction of a Bureau of Highways. By means of lantern slides he illustrated modern appliances for and methods of performing the work of such a bureau, and the results secured by efficient organization.

A vote of thanks was extended the speaker and the meeting adjourned.

WILLIAM E. BULLOCK,
Acting-Secretary.

Mining and Metallurgical Section.—A joint meeting of the Philadelphia Section of the American Society of Mechanical Engineers and the Mining and Metallurgical Section of the Institute was held in the Hall of the Institute on Thursday, January 14, 1915, at 8 P.M.

Professor H. E. Ehlers and Professor A. E. Outerbridge, Jr., presided.

Professor Outerbridge introduced Mr. Robert R. Abbott, B.S., E.M., Metallurgical Engineer, the Peerless Motor Car Company, Cleveland, Ohio, who presented a communication, entitled "Modern Steels and Their Heat Treatment." After considering the mixtures and compounds of iron and carbon present in steels, the proportions of these contained in steels of different carbon contents, and their influence upon the strength of the material as indicated by percentage reduction in area in tension, the speaker described the effect upon the iron-carbon constituents produced by alloying with the iron other elements, such as nickel, chromium, manganese, etc. He then compared with this latter the effects produced by heat treatment, showing that such effects were practically the same as those produced by alloying. He concluded with an outline of the commercial applications of heat-treated steel. The speaker illustrated his remarks by means of lantern slides of photomicrographs and charts.

The paper was discussed by Professor A. E. Outerbridge, Jr., Professor E. Marburg, Mr. H. V. Wille, Dr. Carl Hering, and others.

A vote of thanks was extended the speaker and the meeting adjourned.

WILLIAM E. BULLOCK,
Acting-Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, January 13, 1915*).

RESIDENT.

PROF. H. JERMAIN MAUDE CREIGHTON, Swarthmore College, Swarthmore, Pa.
MR. JOHN S. ROOKE, Edw. Harrington Son & Co., Seventeenth and Callowhill Streets, Philadephia, Pa.
MR. CLARKE THOMSON, 526 Land Title Building, Philadelphia, Pa.

NON-RESIDENT.

MR. LYLE STOCKTON ABBOTT, 281 Newfield Street, East Orange, N. J.
MR. R. R. M. CARPENTER, Wilmington, Del.
MR. W. W. COE, Pocahontas Coal and Coke Company, Roanoke, Va.
MR. EDWARD HEITMANN, Can. Crocker-Wheeler Company, St. Catharines, Ont.
PROF. I. M. RAPP, Ursinus College, Collegeville, Pa.

CHANGES OF ADDRESS.

MR. F. M. MASTERS, Chief Inspector, No. 9 North Front Street, Harrisburg, Pa.
MR. WILLIAM M. SCOTT, Box 76, Radnor, Pa.
MR. JOHN R. TITZEL, Gas Engineer, 61 Broadway, New York, N. Y.

NECROLOGY.

Theodore Armstrong was born in New York, N. Y., in 1840. In 1861 he enlisted in the Union Army, in which he served with distinction. In 1864 he became auditing clerk in the internal revenue office in Philadelphia, and in the following year he accepted the position of chief accountant at the Pennsylvania Salt Company's Natrona factory. He was later made secretary of this company in Philadelphia, then vice-president, and in 1888 was elected president, serving in that capacity for many years. He was a member of the Union League, the Manufacturers' Club, the American Chemical Society, and other prominent organizations. He was elected to membership of The Franklin Institute in 1903.

William Penn Evans was born in Bridgeport, Pa., and received his technical education in the Polytechnic College, Philadelphia, Pa.

His first work was with R. S. Newbold & Son, the Eagle Iron Works, Norristown, Pa. He left the Eagle Iron Works in September, 1872, to accept a position with The Baldwin Locomotive Works, in the Drafting Department, and he continued service with this company, with the exception of a brief interval, until the time of his death. In 1876 he obtained a leave of absence to act as Assistant Superintendent of the Philadelphia and Reading Terminal at the Centennial Exposition, and in 1879 he left The Baldwin Locomotive Works to accept the position of Mechanical Engineer of the Missouri, Kansas and Texas Railroad, at Sedalia, Mo. After one year's service, he returned to The Baldwin Locomotive Works and was appointed Chief Draftsman in 1885, which position he held until 1903. In 1904 he was placed in charge of the exhibit of The Baldwin Locomotive Works at the Louisiana Purchase Exposition at St. Louis, Mo., and upon his return to Philadelphia at the termination of the Exposition was made General Night Superintendent. In 1905 he was given charge of the exhibit of The Baldwin Locomotive Works at the Lewis and Clark Exposition at Portland, Ore., and when this exhibit was closed was appointed Northwestern Agent, with headquarters at Portland, Ore. He continued in this position until 1910, when he returned to Philadelphia and was appointed General Inspector, which position he held until the time of his death.

He was a member of the American Society of Mechanical Engineers, the Engineers' Club of Philadelphia, and the Historical Society of Pennsylvania. He was elected to membership in The Franklin Institute in 1897, served on its Committee on Science and the Arts from 1898 to 1900, and was appointed Chairman in the latter year.

Henry Gurney Morris was born in Philadelphia, Pa., in 1839. He was graduated from Haverford College and became a member of the firm of Morris, Tasker & Co., the first manufacturers of iron pipes in Philadelphia. He later became owner of the Southwark Foundry and a director of the Pennsylvania Steel Company. He was the patentee of a number of mechanical and electrical inventions, including centrifugal machines, brick moulding and pressing machines, centrifugal mixers, electric fans, storage batteries, and electric vehicles. In collaboration with Pedro G. Salom, he made a number of valuable contributions to the development of the horseless vehicle some twenty years ago. He was a member of the American Society of Mechanical Engineers, the American Society of Mining Engineers, and the American Society of Civil Engineers. He was also associated with the Union League and the Engineers' Club of Philadelphia. He was elected to life membership of The Franklin Institute in 1861, served on its Board of Managers from 1864 to 1869, and was vice-president from 1870 to 1879.

WILLIAM PENN EVANS

LIBRARY NOTES.

PURCHASES.

American Annual of Photography, vol. 29, 1915.

BRINTON, W. C.—Graphic Methods for Presenting Facts. 1914.

ELLENWOOD, F. O.—Steam Charts; also a Table of Theoretical Jet Velocities. 1914.

HOOVER, THEO. H.—Concentrating Ores by Flotation. 1914.

LORENZ, HANS.—Neue Theorie und Berechnung der Kreiselräder. 1911.

MACKENZIE, JOHN E.—The Sugars and Their Simple Derivatives. 1913.

MORGAN, J. L. R.—Elements of Physical Chemistry. 1914.

MORSE, SAMUEL F. B.—His Letters and Journals, edited by his son. 2 volumes. 1914.

PRICE, GEORGE M.—The Modern Factory, Safety—Sanitation—Welfare. 1914.

SHERMAN, HENRY C.—Food Products. 1914.

VULTÉ, H. T., and VANDERBILT, S. B.—Food Industries. 1914.

GIFTS.

American Institute of Mining Engineers, Transactions, vols. xlvi and xlvii. New York, 1914. (From the Institute.)

American Iron and Steel Association, Second Supplement to Directory of Iron and Steel Works. Philadelphia, 1912. (From the Association.)

American Society of Heating and Ventilating Engineers, Transactions, 1913 and 1914. New York, 1914. (From the Society.)

Amherst College, Catalogue. Amherst, 1914. (From the College.)

Armour Institute of Technology, May Bulletin. Chicago, 1914. (From the Institute.)

Bonnell, W. A. Company, Catalogue No. 203. New York, no date. (From the Company.)

British India Forest Administration, Annual Return of Statistics, 1912–13. Simla, 1914. (From the Government Printing Press.)

Buffalo Scale Company, Catalogue No. 502. Buffalo, no date. (From the Company.)

Builders' Iron Foundry, "An Appreciation of Two Great Workers in Hydraulics." Providence, London, 1912. (From the Foundry.)

Burnet, John, Essays on Art. Philadelphia, 1913. (From Mr. John Bartlett.)

Butcher, W., & Sons, Ltd., Catalogue "The Camera House." London, 1914. (From the Company.)

Canada Department of Mines, Gypsum in Canada. Ottawa, 1913. (From the Department.)

Canada Department of Trade and Commerce, Report, part i. Ottawa, 1914. (From the Department.)

Carnegie Endowment for International Peace, Limitation of Armament on the Great Lakes. Washington, 1914. (From the Endowment.)

Connersville Blower Company, Catalogue No. 16. Connersville, no date. (From the Company.)

Dartmouth College, Catalogue. Concord, 1914. (From the College.)

Grand Rapids Public Library, Forty-third Annual Report. Grand Rapids, 1914. (From the Library.)

Hess Flume Company, Catalogue No. 214. Denver, 1914. (From the Company.)

Interstate Commerce Commission, Twenty-eighth Annual Report, part i. Washington, 1914. (From the Commission.)

Lake Mohonk Conference on the Indian and other Dependent Peoples, Thirty-second Annual Report. Mohonk Lake, 1914. (From the Conference.)

La Plata Universidad Nacional, Anuario. La Plata, 1914. (From the University.)

Library of Congress, A List of Geographical Atlases, vol. iii, Report. Washington, 1914. (From the Library.)

Literary and Philosophical Society of Liverpool, Proceedings, 1912–1914. Liverpool, 1914. (From the Society.)

Massachusetts Institute of Technology, Catalogue. Boston, 1914. (From the Institute.)

Master Car Builders' Association, Proceedings, vol. 48, parts 1 and 2. Chicago, 1914. (From the Association.)

National Academy of Sciences, Memoirs, vol. xii, part i. Washington, 1914. (From the Smithsonian Institution.)

North Carolina Geological and Economic Survey, Economic Paper No. 34. Raleigh, 1914. (From the Survey.)

Ontario Agricultural and Experimental Union, Thirty-fifth Annual Report, 1913. Toronto, 1914. (From the Agricultural Department.)

Ontario Department of Agriculture, Annual Report of Farmers' Institute. Toronto, 1914. (From the Department.)

Pelton Water Wheel Company, Catalogues of Water Wheels. San Francisco, no date. (From the Company.)

Penberthy Injector Company, Catalogue No. 26. Detroit, no date. (From the Company.)

Pennsylvania Statutes-at-Large, 1682 to 1801, vols. xv and xvi. Harrisburg, 1911. (From the State Librarian.)

Pennsylvania Topographic and Geologic Survey, Report No. 9. Harrisburg, 1913. (From the State Librarian.)

Pennsylvania Water Supply Commission, Reports, 1910, 1911, 1912. Harrisburg, 1914. (From the State Librarian.)

Powell, Wm. Company, Catalogue No. 10, second edition. Cincinnati, 1911. (From the Company.)

Republic of Uruguay, Annual Statistics, 1909–10. Montevideo, 1912. (From the General of Statistics.)

Royal Astronomical Society of Canada, The Observer's Handbook. Toronto, 1915. (From the Society.)

Smithsonian Institution, Secretary's Report. Washington, 1914. (From the Institution.)

Staffordshire Iron and Steel Institute, Proceedings. Stourbridge, 1914. (From the Institute.)

Tasmania Secretary for Mines, Report, 1913. Hobart, 1914. (From the Secretary.)

Union Pacific Railroad Company, Seventeenth Annual Report. New York, 1914. (From the Company,)

U. S. Coast and Geodetic Survey, Special Publications Nos. 19 and 22, Superintendent's Annual Report. Washington, 1914. (From the Survey.)

University of Minnesota, Bulletin No. 11. Minneapolis, 1914. (From the University.)

University of Oklahoma, Biennial Report. Norman, 1914. (From the University.)

Upson Nut Company, Catalogue of Nuts and Bolts. Cleveland, 1914. (From the Company.)

Vassar College, Fiftieth Annual Catalogue. Poughkeepsie, 1914. (From the College.)

Wabash Railroad Company, Twenty-fifth Annual Report. St. Louis, 1914. (From the Company.)

Wyoming State Auditor, Biennial Report. Laramie, 1914. (From the State Auditor.)

Yale University, President's Report. New Haven, 1914. (From the University.)

CORRESPONDENCE.

THE UNIVERSITY OF NEBRASKA,
LINCOLN.

DEPARTMENT OF ELECTRICAL ENGINEERING.
OLIN J. FERGUSON, *Professor.*
V. L. HOLLISTER, *Associate Professor.*
IVAN M. KIRLIN, *Instructor.*

December 29, 1914.

R. B. OWENS, Editor,
Philadelphia, Pa.

DEAR SIR:

The papers by Dr. Humphreys upon "The Thunderstorm and Its Phenomena" have interested me very much, and I wish to offer a comment upon the matter of beaded lightning, which subject he mentions in the December number of the JOURNAL, page 764.

In the spring of 1914 a violent thunderstorm swept over Lincoln at about nine o'clock at night. There were numerous vivid lightning displays. One of these discharges occurring in the storm front originated at an elevation of about 45 degrees from my viewpoint and struck almost vertically downward. I was watching the storm from the window of a dark room, and the flash occurred directly in front of me. It was a direct stroke of chain or streak lightning.

However, in dying away, it took probably a full second to disappear, and in doing so it broke up seemingly into detached portions, short and numerous. In fact, it gave a bead-like effect, and it would be very easy for one to have retained the latter impression and to have called the stroke bead lightning.

In explanation of this phenomenon I would suggest that each bead probably represents the "end-on" view of the irregular portions of the lightning path, and that they remained luminous during the subsequent lesser discharges, while the intermediate sections became non-luminous, because viewed from the side. This theory is borne out by photographs taken with the rotating camera, where it is evident that the later discharges are not necessarily of as great an intensity as the primary discharge. Fig. 25 in Dr. Humphreys's paper illustrates this well, and I have negative and photographs in my possession which show the same plaid ribbon effect.

I also have three negatives where the so-called dark discharge is evidenced in very short strokes. Granting that this is explainable by the photographic reversal of an overexposure, I do not see why it is necessary to conclude that there is no such thing as a dark discharge. It is the fact that visibility occurs only within a very narrow range of frequencies, and, inasmuch as we do not see the electric discharge itself anyway, it is quite conceivable that a discharge may occur and give rise to phenomena quite different in frequencies from those of visible light, and that these phenomena may affect the photographic plate in the manner noted.

You will note that I am advancing no data or experimental proof for this latter statement. This is because I have none and am simply theorizing. However, I see nothing inconsistent in my line of thought.

Very sincerely yours,

O. J. FERGUSON.

BOOK NOTICES.

MECHANICAL LABORATORY METHODS. By Julian C. Smallwood, M.E., Associate Professor Experimental Engineering, Syracuse University. New York, D. Van Nostrand & Company, 1914. 333 pages, 95 illustrations, 12mo. Price, $2.50.

In attempting to describe his book, the author, in the preface, says that he "finds thoughts uppermost of what it is intended not to be," and follows by stating that he does not attempt to cover all the instruments or methods of any class, and he expects the students, for whom the work has been especially prepared, to know the principles and purposes of the various instruments used in the tests before starting to work with them.

One of the first principles announced is the comparative worthlessness of *single determinations,* and he then states that "it is only by repeated trials that accurate conclusions can be framed." This is a very important point for beginners, and it is fortunate to have this axiom so clearly stated, in order to guard against immature reports. The care that should be given to proper calibration of instruments prior to their use is prominently set forth and especial attention is called to points in this preparatory work that are likely to be overlooked. As an example of this may be quoted the 18 pages devoted to the corrections needed to overcome the irregularities in the drum motion of steam engine indicators. The calibration of "flow meters" also occupies 34 pages.

Part 2, on fuel and combustion, is very complete and interesting, and treats of solid, liquid and gaseous fuels in boilers and internal-combustion engines.

In his section on friction tests no mention is made of the elaborate brake-shoe tests of the Master Car Builders' Association, nor of any of the special methods used in this work. Nor is locomotive testing referred to, although this requires quite a different treatment from stationary boilers and engines.

In connection with the ordinary methods of obtaining the clearance volume of steam engine cylinders, the Clayton method is referred to, although it is recommended only where the clearance is large, as in internal-combustion engines. In steam engines it would be hardly expected to give accurate results, as the condensation and re-evaporation during expansion would destroy the accuracy of the PV curve. He treats of this also under steam consumption for determining the quality of steam at cut-off, but says that this method has not been sufficiently verified for general application, which indicates that it should be used with caution until further developed. We think that this is sound logic, and that the more accurate methods should be followed, even if more laborious.

In his chapter on making reports of tests, he states that when it is not considered necessary to furnish tables in full a sample set may be submitted. It seems to the writer, however, that full reports are always desirable, even if placed in the appendix, as at a later date it may be desirable to glean from the tests some conclusions not considered necessary when the test was made. It is for this reason that the reports from the Pennsylvania Railroad Testing Plant are so valuable, as many lines of study can be made from them not specifically investigated in connection with the published reports.

In conclusion, we believe that the book will be found useful to those for whom it is intended; the style is good and the typography clear.

George R. Henderson.

Laboratory Manual for the Detection of Poisons and Powerful Drugs. By Dr. William Autenrieth, University of Freiburg i. B. Translated by W. H. Warren, Ph.D. Fourth edition. Philadelphia, P. Blakiston's Son & Company, no date. 315 pages, 25 illustrations, index and table of contents, 8vo. Price, $2.

A fourth edition usually offers to the reviewer little opportunity for new criticism, but the translator of this work tells us that much new matter has been added and the text somewhat rearranged.

The work is a comprehensive and convenient guide to the toxicologist, including, as it does, a long list of poisons and the modern qualitative and quantitative procedures. The reviewer cannot forbear to say that the time seems now to be past in which American analysts need to rely for general text-book assistance on European authorities. The procedures in toxicology, industrial analysis, and examination of food and drugs that have been developed by American workers are in all respects as satisfactory as those that come from abroad, though, of course, long established—so-called "classic"—methods are still important, but these are available in all text-books. It is to be hoped that the translator of this volume or some equally competent American chemist will soon furnish us with a "made in America" manual.

A notable and useful addition to the present work, contributed by the translator, is a discussion of the so-called "normal" arsenic; that is, the existence of arsenic in the human body as an essential constituent. Dr. Warren rightly objects to the word "normal" in this connection, and from an extended study of the literature comes to the view that the likelihood of arsenic being naturally in the body is too remote to concern the practical toxicologist.

The reviewer thinks that the numerous structural formulas in the book are out of place. The work is a laboratory manual, not an introduction to organic chemistry.

HENRY LEFFMANN.

OPTIC PROJECTION: Principles, Installation, and Use of the Magic Lantern, Projection Microscope, Reflecting Lantern, and Moving-picture Machine. By Simon Henry Gage and Henry Phelps Gage, Ph.D. Ithaca, N. Y., The Comstock Publishing Company, 1914. 703 pages, index, plates and illustrations, 8vo. Price, $3.

This work fills a great want. The enormous increase in the use of projection methods in the class-room, as well as in public lectures, has rendered necessary some comprehensive account of the principles underlying the several systems, and of the methods for securing the best results. The commercial production of electricity and the advance in high-speed photography have greatly increased the facilities for obtaining and projecting lantern slides; the perfecting of the opaque projection and the motion-picture apparatus has added extensive fields of illustration.

The principles on which projection apparatus is constructed and operated are far from simple, and much of the information has been obtainable only from foreign sources or from manufacturers' catalogues. It is, therefore, of much value to American teachers that a book of comprehensive character and independent attitude is presented. The theory and practice of all phases of projection apparatus are fully explained and the dangers and difficulties of operation are set forth.

The work will have a large sale, and the first edition will soon be exhausted. The reviewer desires to call attention to a defect which it is hoped that the authors will note and avoid in subsequent editions. The book is greatly over-illustrated. The topics are mostly such as need illustration, but it is mere trifling to insert full-page pictures from manufacturers' catalogues. The use of a great many half-tones renders a heavy paper necessary, making the book cumbersome. An equally satisfactory consideration of all topics could have been presented with half the illustrations.

HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

U. S. Bureau of Mines: Bulletin 77, The Electric Furnace in Metallurgical Work, by Dorsey A. Lyon, Robert M. Keeney, and Joseph F. Cullen. 216 pages, illustrations, 8vo. Technical Paper 94, Metal-mine Accidents in the United States during the Calendar Year 1913, compiled by Albert H. Fay. 73 pages, 8vo. Fourth Annual Report of the Director of the Bureau for the Fiscal Year Ended June 30, 1914. 101 pages, 8vo. Washington, Government Printing Office, 1914.

Canada Department of Mines, Mines Branch: Gypsum in Canada: Its Occurrence, Exploitation, and Technology, by L. H. Cole. 256 pages, illustrations, plates, maps, 8vo. Ottawa, Government Printing Bureau, 1913. The Production of Coal and Coke in Canada during the Calendar Year 1913, by John McLeish, B.A., Chief of the Division of Mineral Resources and Statistics. 40 pages, 8vo. Ottawa, Government Printing Bureau, 1914.

Armour Institute of Technology: Bulletin, May, 1914, General Information Number. 199 pages, plate, 8vo. Chicago, Institute, 1914.

University of the State of Iowa: Bulletin, New Series, No. 87, University Extension Bulletin No. 8, Water Works Statistics of Thirty-eight Cities of Iowa, with the Meter Rates of Seventy Cities, by John H. Dunlap. 52 pages, 8vo. Iowa City, University, 1914.

The Water Power Problem in the United States, by Rome G. Brown. Reprinted from the *Yale Law Journal,* November, 1914. 33 pages, 8vo.

Harrison Safety Boiler Works, Cochrane Multiport Valves. 72 pages, illustrations, 8vo. Philadelphia, Harrison Safety Boiler Works, 1914.

American Pulley Company, Data Sheets. 36 pages, illustrations, 4to. Philadelphia, The American Pulley Company, 1914.

Protective Coating for Furnace Electrodes. (*Metallurgical and Chem. Engin.,* xii, 533.)—S. H. Fleming proposes to produce a coating of titanium nitride on furnace electrodes and other refractory materials. Titanium nitride is stable at high temperatures, is nonporous, tough, and hard, and otherwise possesses qualities that make it valuable as a protective coating for substances that are subjected to very high temperatures in an electric or other furnace. In order to form a coating a mixture of rutile and some binder is pressed on the article to be coated, which is then baked at a high temperature in the presence of nitrogen. Owing to the great affinity of Ti for nitrogen, the former is converted into nitride. A first coating of titanium carbide may be desired, as this substance wets carbon and enters the pores of its exterior surface and forms a perfect union with the carbon. This may be formed by applying a mix of titanium and carbon and heating with exclusion of air, forming titanium carbide. After the coating of carbide is formed the article may be heated in an atmosphere of nitrogen, thus converting part of the carbide into nitride. This latter conversion may be stopped before all of the carbide has been changed, if an inner coating of carbide is desired.

CURRENT TOPICS

The By-product Coking Industry. G. S. Cooper. (*Iron and Steel Inst.*, 1914.)—The Koppers combination oven can be operated as a gas oven with blast-furnace gas instead of with producer gas, and by consuming all available blast-furnace gases in this way a maximum amount of coke-oven gas becomes available in iron and steel works for heating open-hearth furnaces and for other purposes. The coal used for coking should not yield, on distillation, more than 7 to 8 per cent. water, reckoned on the dry coal. The coking character of Scotch coals deteriorates with exposure. The Koppers process for the direct recovery of ammonia from coke-oven gas has now been applied for the first time to coal gas at the Budapest gas works. The crude gas is cooled to 25° C., and delivered by an exhauster to the tar extractor. The gas is then reheated to 50° or 60° C. and treated with sulphuric acid in a closed saturator from which ammonium sulphate is removed continuously by an ejector working with steam or compressed air. The liquor from the cooler and tar-extractor is separated from tar and distilled with lime, the gases being delivered to the hot gas entering the saturator. The gas from the saturators is cooled and scrubbed with creosote oil for the recovery of benzene. The yield of benzene from coke-oven gas varies from 1 to 1½ gallons in South Wales to 2½ to 3 gallons per ton of coal carbonized in South Yorkshire, Derbyshire, the Midlands, and Cumberland. In open-hearth steel furnaces the durability of bulkheads and roofs is decreased by 8 to 10 per cent., and that of the chequer-work increased by 50 per cent., by the use of coke-oven gas. At Friedrich Wilhelmshütte the consumption of coal per ton of steel was reduced from 31.8 to 14.9 per cent.

Effect of Addition Agents in the Electro-deposition of Iron. O. P. Watts and M. H. Li. (*Amer. Electrochem. Soc. Trans.*, xxv, 529.)—The electrolyte chosen as a basis for the addition of various substances consisted of 150 gm. of crystallized ferrous sulphate and 75 gm. of ferrous chloride ($FeCl_2, 4 H_2O$) per litre, and had a specific gravity of 1.125 at 20° C. Ammonium sulphate (120 gm. per litre) gave good results as an addition agent; the sodium, magnesium, and aluminum sulphates were not satisfactory. Using the solution containing ammonium sulphate, the effect of 48 organic addition agents was tried; of these, only ammonium oxalate and hexamethylene tetramine improved the remarkably smooth and satisfactory deposit given by the original electrolyte. Solutions of ferrous ammonium fluosilicate or fluoborate are not satisfactory electrolytes.

Dissociation of Hydrogen into Atoms. I. LANGMUIR and G. M. J. MACKAY. (*J. of Amer. Chem. Soc.*, xxxvi, 1708.)—Evidence in favor of the view that at high temperatures hydrogen is dissociated into atoms is summarized as follows: The loss of heat from electrically-heated tungsten wires in nitrogen, mercury vapor, argon, and carbon monoxide varies with the temperature exactly in accordance with theory. In hydrogen, however, the loss of heat rapidly increases above 1900° K. (K. signifies absolute scale of temperature), and at 3500° K. is more than four times the calculated value; no secondary electrical effects capable of explaining the increase can be detected. At low pressures the loss of heat from tungsten wires is greater than at atmospheric pressure in hydrogen, but not in other gases. When a wire of tungsten, platinum, or palladium is heated above 1300° K. in hydrogen at a very low pressure (0.001 to 0.02 mm.) the hydrogen slowly disappears. It is not absorbed by the wire, but is deposited on the glass (sometimes in tubing a long distance from the bulb), especially when this is cooled by liquid air; ordinary hydrogen is liberated when the cooled portions are heated. The hydrogen which deposits in this way on glass is very active chemically, reacting with oxygen and phosphorus at the ordinary temperature. It is capable of diffusing through long tubes (at low pressures), and will then dissolve in platinum (at 50° C.), causing a marked increase in the electrical resistance of the metal and a corresponding decrease in its temperature-coefficient. The active hydrogen is not affected by an electrostatic field and therefore does not consist of hydrogen ions. Tungstic oxide, platinum oxide, and other substances contained in a tungsten filament lamp, together with hydrogen at very low pressure, are rapidly reduced when the filament is heated above 1700° K., although otherwise they are not affected by hydrogen.

Ammonium Sulphate Plant at Fushun, China. (*Board of Trade J.*, July 2, 1914.)—A Mond gas plant is being installed at the Fushun coal mines, in Manchuria, to supply power for use in generating electricity. This plant has been specially designed for the recovery of ammonium sulphate, Fushun coal being particularly suitable for this purpose, and it is estimated that 250 tons of coal will be gasified per day, and that there will be a daily yield of about 12 tons of sulphate. The intention is to sell this sulphate in Japan or California.

Transformations of Steels. H. DE NOLLY and L. VEYRET. (*Iron and Steel Inst.*, 1914.)—In the authors' view, the transformation-point is marked by the allotropic change of α- into β- or γ-iron, with a more or less complete dissociation of carbide and solution of the carbon liberated in γ-iron. If it be admitted that the allotropic change involves shrinkage, and that the dissociation and solution involve dilatation, this view is supported by the numerous dilatation curves given for steels of various composition.

The Kelp Industry. ANON. (*Report to the Board of Agriculture for Scotland on Home Industries in the Highlands and Islands,* 1914, 118.)—There has been a marked increase in the production of kelp since 1905, and the conditions are favorable for further extensions and developments, especially in respect to improved methods of collection and utilization, since the South American sodium nitrate deposits, from which four-fifths of the present supply of iodine is derived, are being gradually depleted. The Scottish sea-weeds are considerably richer in iodine than the giant kelps of the Pacific and the Japanese sea-weeds. Two methods of utilization of the algæ are available, the dry method of burning or carbonizing, and the wet method, although up to the present the latter has proved expensive in actual commercial working. In the United States a large company is now engaged in the manufacture of potassium salts from kelp on a commercial scale. The kelp is collected at sea by a boat fitted with a power-driven cutting device which can be lowered to about 8 feet below the keel. From the boat the kelp is delivered to an elevator and carried to a closed drier, in which it is kept in constant motion at not above 100° C. The drying should follow as soon after collection as possible, since the value of the sea-weed is reduced by exposure to the air. The dried weed is calcined at not above 400° C., in a brick kiln having a fire-clay lining and a cast-iron grate through which air enters. The volatile products pass to condensers through a tar chamber kept at a uniform temperature at the top and superheated at the bottom. The ash is treated for the recovery of potassium salts, iodine, etc. The products manufactured are: calcium, sodium and magnesium sulphates, potassium chloride, cyanide, chlorate and nitrate, sodium chloride, calcium carbonate, carbon, iodine, bromine, ivory black, varnish gum, creosote, alcohol, acetone, and combustible gas.

Effect of a Longitudinal Magnetic Field on Spark Potentials. R. F. EARHART. (*Phys. Rev.*, iv, Ser. ii, 135.)—The conclusions reached are that, using parallel plate electrodes, electric and magnetic fields parallel: (1) Spark potentials for pressures above the critical pressure are unaffected by the longitudinal magnetic field. (2) Those below the critical pressure are decreased by such a field. (3) When the pressure exceeds the critical value, the existence of the field requires a higher potential to maintain the discharge than if no field existed. (4) The variations noted in (3) are increased with increasing fields and become larger as the gas pressure is increased.

Electricity for the Household in Venezuela. ANON. (*Sci. Amer.*, cxi, No. 12, 223.)—The electric power company which supplies the city of Caracas, Venezuela, with electric light has recently installed day service, and hopes to educate the people to the use of electric stoves, irons, fans, etc. Electric heat and power are ideal for tropical countries. It may take some time to educate the Venezuelans to its advantages, but eventually it should prove indispensable.

A New Constant of Glass; the Cohesion-point. E. ZSCHIMMER. (*Silikat-zeits.*, ii, 129.)—When two clean, plane, polished glass surfaces are pressed together a firmly-adhering combination is obtained, in which, however, the surfaces are separated by an air layer at least 0.047 mm. thick, and a grayish-blue interference color is produced. The condition is merely one of *adhesion;* the intimate molecular contact of the glass which is the necessary condition for *cohesion* between the two surfaces is wanting. At high temperatures the adhesion slowly passes within a certain length of time into cohesion. The temperature required to cause this in a specified time is named the *cohesion-point.* It is a constant of the particular variety of glass, which relatively defines its specific softening properties, and allows the course of liquefaction to be exactly followed. It is, in fact, a substitute for the melting-point constant of crystalline substances. If cohesion-points are plotted against corresponding times of heating a representation of the softening of the heated glass is obtained. In practice 30 minutes may be adopted as the standard time of heating required to effect coherence of the surfaces. The glass, in the form of disks, 10 mm. diameter and 2 mm. thick, adhering in pairs, is heated in an electric tube furnace. The course of the coherence is easily followed; a black spot surrounded by Newton rings first appears, and gradually increases in size, eventually, at the completion of coherence, extending over the whole disk. The endpoint is easily recognized. Numerous tables and curves are given showing the values of the constant for many varieties of glass.

Production of Steel Direct from Ore. E. HUMBERT and A. HETHEY. (*Iron and Steel Inst. Journ.*, lxxxix, 378–391.)—The authors have carried out experiments on the production of steel direct from the ore, as compared with the usual method of working with pig iron. Experiments were made in a normal Héroult electric furnace of 6 tons capacity, worked with single-phase current. Three series of tests were made, namely: (1) Direct reduction of siliceous Swedish iron ore. (2) Direct reduction of Swedish and a siliceous Swedish iron ore, with 30 per cent. of scrap mixed with the charge. (3) Direct reduction of Brazilian iron ore. Figures are given showing the composition of the charge, energy used, analyses, etc. It was found that good steel could be obtained without the carbon being above 0.4 per cent. at any time. The steel forged well and welded easily. The consumption of the electrodes was at the rate of 32 kg. per ton of steel. The wear of the lining was approximately the same as when melting scrap, but there was a good deal of ebullition, owing to the liberation of large volumes of oxide of carbon. The outstanding quality of steel by this process is its toughness. The authors claim that the steel is more free from harmful gases, such as nitrogen, by this process, and that the direct method has the advantages of simplicity, ability to use refractory and richer ores, freedom from impurities, cheapness, and efficient control of the quality of the steel.

A Powerful Magnet. A. COTTON. (*Electr. World*, lxiv, No. 11, 531.)—This article describes the work which has been so far done on the project of installing a powerful magnet at the University of Paris to permit experiments with fields of 100,000-gauss intensity. The University has granted $10,000 for the purpose. Weiss and Cotton have proposed the construction of a very large electromagnet of the Weiss type, weighing about 200,000 pounds. Deslandres and Perot have proposed the construction of various apparatus of smaller size of their own design. The commission is in favor of the first project. A review is given of the whole subject of electromagnet design. First he discusses electromagnets without iron core. He examines the form to be given to the coil and the method of winding, and the energy necessary to produce a certain field in the interior. He next discusses means of getting rid of the Joulean heat in the magnet winding. Then he takes up the design of an electromagnet with an iron core, and refers to the work of P. Weiss, who uses ferro-cobalt for the central part of the pole pieces, since in this way fields 10 per cent. higher than with pure iron can be obtained. He then discusses the problem how to proceed in enlarging a given electromagnet design to one of much larger dimensions. In the second part of the paper details are given of the electromagnet design of Deslandres and Perot and of Weiss's electromagnet with polar coils. A magnet such as is wanted by the University of Paris would cost $40,000, so that the available grant is not yet sufficient.

Effect of Titanium on the Magnetic Properties of Iron. K. P. APPLEGATE. (*Rensselaer Polytechnic Inst., Engin. and Science Series*, No. 5, 1914.)—To reduce hysteresis loss, iron is made magnetically softer by annealing or by the addition of foreign material. The addition of elements of low atomic weight, such as Si and Al, has been found to be particularly advantageous. Some of the effects of titanium are as follows: A decrease in hysteresis and an increase in permeability were obtained with Ti when less than 1 per cent. of that metal was used, an increase of hysteresis taking place with further increase of the metal. Prolonged annealing at 760° C. does not soften the material; since commercial Ti alloys cause deterioration in quality, the pure metal must be employed. Finally, titanium steels are not so good as the present standard silicon steels.

Spectrum of the Chromosphere. P. SALET and MILLOCHAN. (*Comptes Rendus*, clviii, 1000.)—Several photographs of the spectrum of the solar chromosphere have been made with the large spectrograph attached to the equatorial of the Paris Observatory, the solar limit being doubled by Condé interposing an Iceland spar rhomb. The chromospheric lines showed almost the same appearance in the two spectra, thus suggesting that the Stark effect due to a possible magnetic field is very feeble, if at all existent. It is hoped to test the method further by means of greater dispersion apparatus.

American Steel Rails. ANON. (*Eng.*, xcviii, No. 2541, 322.)—The production of steel rails in the United States last year was 3,502,789 tons. The corresponding production for each year of the decade ending with 1913 inclusive was:

Years.	Tons.	Years.	Tons.
1904	2,284,711	1909	3,023,845
1905	3,375,929	1910	3,636,031
1906	3,977,887	1911	2,822,790
1907	3,633,654	1912	3,327,915
1908	1,921,015	1913	3,502,789

The great extent of the American railroad network ensures a good annual demand for steel rails for renewals, but current American railroad construction does not exhibit the vigor and energy of former years, and it is significant that American railroad bonds to the aggregate amount of $578,673,000 are at present in default with respect to their interest.

Correction for Determining the Heating Value of Coal to be Applied on Account of the Oxidation of the Sulphur Compounds and of the Nitrogen in the Bomb Calorimeter. S. H. REGESTER. (*J. Ind. Eng. Chem.*, vi, 812.)—The results of the experiments indicate that the relative amounts of sulphur trioxide and dioxide in the bomb gases after combustion depend chiefly on the amount of nitrogen oxides formed in the bomb, which promote the formation of the trioxide just as in the manufacture of sulphuric acid by the chamber process; the ash of the fuel does not appear to exert any appreciable catalytic action. The formation of nitrogen oxides takes place much more readily from the nitrogen of the coal than from the nitrogen present in the bomb gases, and increases with increasing pressure and with the heat of combustion of the fuel. The usual correction applied to the heating value of a fuel, according to the sulphur content, based on the assumption that the sulphur is converted completely into sulphur trioxide in the calorimeter, is satisfactory in the case of coal with less than 2 per cent. sulphur, burnt in a bomb calorimeter from which the initial charge of air is not removed by rinsing out with oxygen; in the case of coals high in sulphur, a material amount of sulphur may be left as sulphide in the ash and as sulphur dioxide in the gas. If the air in the bomb be blown out with the oxygen of high purity, so that the concentration of nitrogen in the bomb is only a fraction of 1 per cent., then, with a fuel free from nitrogen, only a part of the sulphur will be converted into sulphur trioxide. With a non-nitrogenous fuel containing less than 0.08 gramme of sulphur in the sample burned, approximately quantitative formation of sulphur trioxide is obtained at 20 atmospheres pressure if the nitrogen concentration of the bomb gases be 6 per cent. The heat of combustion to SO_3 of the sulphur of pyrites was found to be about 4975 calories per gramme.

A New Process of Detinning. WALLACE SAVAGE. (*Brass World*, x, No. 11, 436.)—The inventor has discovered that at a temperature below 68° F., and preferably at 32° F., a coating of white tin can be changed to the non-adherent gray tin by the catalytic action of gray tin, applied in the form of a slimy mixture with a solution of tin ammonium chloride. A mixture of about 2500 pounds of gray tin is used with a solution of 10 pounds of tin ammonium chloride in 100 gallons of water. Agitation may be used, or the coated material may be merely moved through this slime.

Latest Developments in Wireless Telegraphy. H. BRAND. (*Verein Z. Beförd. des Gewerbefleisses, Verh.*, No. 4, 225.)—This monograph gives a useful *résumé* of the more recent developments in German wireless telegraph apparatus, a considerable amount of information being given regarding the use of the Telefunken type of wireless compass and of the station at Arkona, which uses this method for giving vessels their bearings in time of fog. The properties of the various types of directive antennæ are dealt with, and doubt is expressed as to the Marconi horizontal antenna giving an energy diagram differing much from a circle; tests at the Telegraphen-Versuchungsant did not, it is stated, show any lateral minimum at all. In any case, it is held that the fact that Glace Bay signals to Clifden are well heard at Buenos Ayres, more than twice as far from Glace Bay than Clifden is, and almost at right angles to the line Glace Bay–Clifden, renders it doubtful whether the antenna has any directive action whatever. The Telefunken compass makes use of the marked directive action of a pair of antennæ, oscillating in opposition of phase, as in the Bellini–Tosi arrangement, but, unlike the latter, requires a large number (8) of such pairs.

Development of Domestic Coal-tar Colors. I. F. STONE. (*Paper read before the New York Section of the American Chemical Society.*)—If the United States are to be independent of Germany, the intermediate products must be made on a large scale. This would require a protective duty sufficient to allow the business to be developed. The present duty of 10 per cent. was insufficient by reason of the convention which controlled the manufacture in Germany, and immediately reduced the price by an equivalent amount. This had happened in the case of aniline oil, the manufacture of which was begun about three years ago by the Schoellkopf Aniline Works at Buffalo, and which now furnished about one-quarter of the consumption of the United States, taking oil and salts as one product. The unfair competition of Germany could be readily checked if the Government would incorporate in its tariff what was known as the "dumping" clause which forbids the importation into and the selling in the United States of any products at a less price than they are sold in the country where they are produced. The Schoellkopf factory produced aniline oil thirty years ago, but had to abandon it on account of being unable to obtain benzol. That was no longer a difficulty; moreover, by-product coke ovens could readily be established to increase the supply. There was also the manufacture of explosives to increase the consumption of intermediate products. No government could afford to be dependent on a foreign supply of such bodies as trinitrololuol and carbolic acid. In self-defence it must create some sort of tariff or subsidy to protect the industry. Dr. Hesse had stated that, out of 900 dyes, 76 were made in the United States. The real number was about 100, and when it was remembered that many of the 900 were defective or obsolete, the proportion was larger than appeared on the surface. They could satisfy 90 per cent. of United States color demands, referring to types not quantities, the remaining 10 per cent. being mainly alizarin and indigo. The amount of dyestuffs imported into the United States of America in 1913 was: Aniline dyes, $7,000,000; indigo, $1,000,000; alizarins, $1,500,000. These were cost prices, and when the United States duty of 30 per cent. and the expenses were added, it meant the Americans were paying about $12,000,000 for their supplies, not including the home manufacture, which might be $2,000,000 more. The author then combated some statements of the *Scientific American* in regard to a protective tariff, and considered that a higher tariff would stimulate production and competition, and that competition would always control the price. Indigo and alizarin were not made in America and there was no duty on them, yet customers had to pay more for them, because their prices were controlled by a combination.

Direct cotton black was made in America, and there was a 30 per cent. import duty on it. In consequence, the Europeans had been compelled to reduce their selling prices in America to less than they were charging their customers in Europe. The author also demanded a revision of the United States patent laws on the lines of the recent British Amendments. In 1909 this was proposed, but Germany negotiated a treaty by which the German working clause was made inoperative on American inventions. Whether this was beneficial was a question, but it certainly did not benefit the United States coal-tar industry. From 1880 to 1883, when there was an import duty of 35 per cent. ad valorem and 50 cents per pound specific, there were ten dye factories in the United States. In 1883 the specific duty of 50 cents was abolished, and within one year five of these factories succumbed, and now only four were left, and these had a great struggle to maintain themselves.

The change in the patent laws was of less importance in the case of colors than in other lines, as there were quite enough dyes on which the patents had expired to constitute a large industry.

America could manufacture dyes if it were made commercially possible, but whenever conditions became normal, without protection, they would have to give up the manufacture of intermediate products, because they could get them cheaper in Europe than they could make them.

Modifications of a Balance for Ease and Quickness of Weighing. G. A. SHAKESPEAR. (*Phil. Mag.*, xxvii, 990.)—In the use of a good physical balance the accuracy of weighing is mainly limited by (*a*) the accuracy of the weights, (*b*) constancy of temperature in the balance case, (*c*) the accuracy with which the position of the rider can be read, and (*d*) the magnitude of the smallest measurable deflection of the beam. Frequently, details (*a*) and (*b*) are not sufficiently regarded. Theoretically, the sensitiveness may be increased so that the smallest appreciable change of position of the rider produces an observable deflection of the beam. In practice, however, it is found advisable to have a degree of sensitiveness for which a comparatively large change of position of the centigramme rider produces no appreciable change in deflection. In other words, the rider is usually too small and the means of measuring deflection not sufficiently delicate. In the balance described the rider is, therefore, comparatively large (either 0.5 or 0.05 Gm.), and the deflection is observed optically by using a concave mirror attached to the beam. The rider beam runs from end to end of the beam, the upper edge being in the plane of the knife-edges. It is divided into ten equal divisions, each of which is divided into ten smaller divisions. The rider is in the form of an elongated ring which surrounds the rider beam, and is provided with a hook at its upper part. The rider is moved by a thin silk cord passing through a slit at each end of the balance case. The effect of using the concave mirror is to provide a pointer of considerable length, but with small mass and moment of inertia, so that the period of oscillation is appreciably reduced. There is, moreover, no parallax. The weights are placed in the right-hand pan, the rider being on the zero mark at the left-hand end of the beam.

Utilization of Gases in Iron Works. K. RUMMEL. (*Zeitschr. Vereines Deutsch. Ing.*, 58, 1153–1160.)—The author reviews present-day applications of coke-oven and blast-furnace gases in iron works; points out the difficulty of predetermining efficiency, and discusses the thermal efficiency and economic aspects of gas utilization in boiler firing, gas engines, regenerative and other ovens, under various conditions. Owing to the importance of the latter it is impossible usefully to abstract the quantitative data given. Capital cost, load factor, and working costs are taken into consideration. The best means of utilizing available gases must be considered with reference to the special circumstances of each installation. The coke oven or blast furnace providing the gas should be considered as an independent concern, wishing to sell gas as dearly as possible. Gas should be used in those applications which will stand the highest charge per 1000 cubic feet. A table is presented showing the actual "value ratio" of purified coke-oven and blast furnace gas of the same thermal value as coal; this ratio varies from 1.0 to 1.45 and is 2.5 : 1 for coke-oven gas as compared with lighting gas. From examples and general considerations in the original it appears that blast-furnace gases are best used in power applications; for the production of blast-furnace draught, for current generation, and, finally, in steel works gas blasts.

Next in the descending scale of advantage comes gas firing in steel works and rolling mills, in Martin ovens, soaking pits, and drying ovens, etc. Gas should be used below steam boilers only as a last resort. On this basis gas-engine plant is preferable to steam turbines, whether the latter be supplied from gas- or coal-fired boilers. Allowing, however, for the difference between gas supply and demand, there is still very useful application for steam plant. Surplus gas supply is best used beneath boilers which are also arranged for coal firing. Steam so produced finds advantageous application in rolling-mill drive, and frequently yields higher overall efficiency than is obtainable from any other equipment. From special cost investigations the author concludes that steam drive is frequently preferable to electric motor drive in heavy rolling mills.

Potash from Felspar and Other Sources. ANON (*Chem. News*, cx, 175.)—In view of the stoppage of supplies of potassium salts from Germany, attention is directed to a process developed by Ward and Wynants (English Patent 3185, December 30, 1857) for the extraction of potassium salts from felspar, which gave satisfactory results. Felspar ground to the fineness of Portland cement was mixed with powdered fluorspar or other fluoride, the fluorine being calculated equivalent to the alkali in the rock. A mixture of chalk and lime was then mixed with the materials so that the proportion of Ca was double that of the SiO_2 and one and a half times that of the Al. On the large scale it was found preferable to use about 10 per cent. excess of lime. The mixture was made into cakes and heated to a yellowish red for a few hours. The porous frit obtained was lixiviated with boiling water, which extracted 90 per cent. of the potash originally present in the rock in the form of hydroxide and carbonate. The residue might be worked up into hydraulic cement by removing the fluorine. Another possible source of potash is the spent wash from the fermentation of molasses from the beet-sugar industry. The wash, neutralized by chalk, is decanted, evaporated, and calcined. The crude ash contains about 50 per cent. of potassium salts. The kelp industry is another source of potash, with the advantage of also yielding iodine.

Fire Clay in Coal Mines. J. W. MELLOR. (*Times. Eng. Suppl.*, Sept. 25, 1914.)—A small number of samples of clay from North Staffordshire coal mines have been tested with satisfactory results, and it is suggested that a valuable source of fire clay is being overlooked. One sample collapsed only at the same temperature as Seger cone No. 33; a good British fire clay collapses at cone No. 30 or 31—*i.e.*, at a lower temperature.

The Nickel-plating of Aluminum. E. TASSILY. (*Rev. de Métallurgie,* xi, 670–673.)—None of the large number of the methods which have been patented for nickel-plating aluminum appears to give satisfaction in practice. Generally, the nickel is deposited on an intermediate coat of copper, zinc, or iron, but even then the adherence leaves much to be desired. A method recently patented by Carnac permits the direct deposition of an adherent coating of nickel which can be polished, will stand hammering and heating, and, in fact, the result behaves so much like an alloy that the author has been led to call it aluminum-nickel. The method consists in passing the metal through a bath of boiling potash, brushing with milk of lime, soaking for some minutes in a 0.2 per cent. potassium cyanide solution, and, finally, treating in a bath of 500 gm. HCl, 500 gm. water, and 1 gm. of iron until the Al assumes a mottled metallic appearance. After each operation the metal is well washed in water. Nickelling is carried out in the ordinary way in a bath containing 50 gm. nickel chloride, 20 gm. boric acid, and 1000 c.cm. of water, using a current at 2.5 volts and a density of 1 amp./dm.^{2} The success of the process appears to depend on the thorough cleaning and the fact that a thin layer of iron is deposited on the Al from the ferruginous bath. That there is a layer of iron on the metal is proved by the fact that on testing by means of the magnetic balance the susceptibility of metal which has been through this bath is 14 times as great as that of the metal which has simply been boiled in potash. Microscopic examination of the surface reveals the presence of small cells in which the Ni is deposited during electrolysis, the process being assisted by the formation of numerous small couples. The resulting product resists the action of moist air, hot and cold acids and alkalies, hot concentrated salt solutions, alcohol, and does not permit the sweating of petrol. Compared with pure Al, the tensile strength is increased, the coefficient of expansion decreased, while the density is only slightly increased. It can be applied in railway construction, shipping, the manufacture of instruments, cooking utensils, and so on.

Fuel Saving through Proper Dimensioning of Steam Piping. GILLEAUME. (*Feuerungstechnik,* vol. xi, No. 14.)—This article argues that fuel can be saved by using higher steam velocities in pipes; the limit for safety with reciprocating engines is 82 to 98 feet per second. The Berlin Electricity Works Company carried out experiments and obtained considerable saving in fuel by eliminating pipes which had been put in to reduce the fall of pressure. Formulæ are discussed with the results of experiments.

PRESS OF
J. B. LIPPINCOTT COMPANY
PHILADELPHIA

JOURNAL
OF
THE FRANKLIN INSTITUTE
DEVOTED TO SCIENCE AND THE MECHANIC ARTS

VOL. CLXXIX MARCH, 1915 No. 3

MODERN VIEWS ON THE CONSTITUTION OF THE ATOM.*

BY
A. S. EVE, D.Sc.,
Macdonald Professor of Physics, McGill University, Montreal.

INTRODUCTION.

THE view that matter is composed of discrete entities, called atoms, which are indivisible, is one of great antiquity. It was, however, merely a speculative opinion, not based on experimental evidence.

At the present day we can affirm that atoms have a real existence, using the word " real " in the ordinary sense; for instance, as a bullet or stone may be considered real. Moreover, it is possible to perform a number of experiments which indicate clearly that atoms are themselves composed of smaller entities, termed electrons, and it is not difficult to obtain some conception of the number and distribution and motion of these electrons within the atom. Furthermore, radio-active elements, such as radium or thorium, consist of atoms in a state of disintegration or devolution, and it has been possible to detect *single* electrons projected from radio-active matter, and also to ascertain that a radium atom may eject the large nucleus of the smaller helium atom. These

---

* Based on a lecture delivered at the meeting of the Section of Physics and Chemistry held Thursday, December 3, 1914.

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

Copyright, 1915, by THE FRANKLIN INSTITUTE.

remarkable expulsions from the inner citadels of certain atoms take place independently of their physical surroundings, such as extremes of pressure and temperature. It is noteworthy, however, that the manner in which these heavy atoms such as uranium and radium are built up from their smaller constituents, remains a profound mystery.

When the seventh Duke of Devonshire presented the Cavendish Laboratory to the University of Cambridge, the first Professor of Experimental Physics appointed was Clerk Maxwell, the Newton of electricity.[1] In his great treatise on " Electricity and Magnetism " he made a notable prophecy; namely, that the discharge of electricity through a rarefied gas is a phenomenon of great interest and importance, and, when better understood, " will probably throw great light on the nature of electricity as well as on the nature of gases and of the medium pervading space."

When Maxwell died he was succeeded by Lord Rayleigh, who found the units of electricity uncertain to some five per cent. This matter needed prompt attention, for electrical supply was then becoming a commercial undertaking. Rayleigh, in a few years, made it possible to determine with good accuracy the volt, the ampère, and the ohm. He retired, owing to his multitudinous duties and interests, and the University of Cambridge was somewhat startled to find the great Chair of Physics conferred on a " boy " of twenty-seven, the illustrious J. J. Thomson.

It would seem that he was born to prove the accuracy of the first half of Maxwell's prophecy, for he promptly investigated electrical discharges in gases, and the timely discoveries of the cathode rays and of Röntgen rays enabled him to make two great forward steps, namely, the theory of gaseous ionization, and a clear view of the nature of electrons.

When a current is passed from metal plates through a highly-exhausted tube a stream of particles is projected from one plate (the cathode). It was known that these were readily deflected by a magnet, but Sir Joseph Thomson succeeded in deflecting them also by an electrostatic field. He thus showed that the cathode particles, or corpuscles, are exceedingly light, with a mass about one-eighteen-hundredth part of the hydrogen atom. These corpuscles are now usually termed electrons, and are the fundamental units or atoms of negative electricity. It is scarcely credible that this most primary conception can ever be dethroned from a foremost place in human knowledge.

---

[1] Maxwell himself termed Ampère the Newton of electricity.

Sir Joseph Thomson also gave us a theory of the manner in which a gas conducts electricity. If the molecules were all uncharged, then he believed that the gas would be a perfect insulator. The current of electricity in a gas is always carried by "ions," or charged molecules of gas which have gained, or lost, one or possibly more electrons. At low pressures or high temperatures the negative electricity may be conveyed by electrons instead of by negative ions; but positive electricity has never been found detached from atoms, or from the nucleus of atoms, so that the term positive electron has at present no concise meaning. Later we shall see Sir Ernest Rutherford's suggested interpretation of it.

It is necessary to write a few words about the radio-active substances, or radiants, as I find it convenient to call them.

There are about thirty-seven radiants known, and they are divided into three great families: (1) uranium-radium, (2) thorium, (3) actinium.

When any one of the atoms disintegrates it projects a fundamental part of the atom, either an alpha ray or a beta ray, with a high velocity into the surrounding space. That which remains of the old atom is a new atom of different physical and chemical properties to the parent atom from which the ejection took place.

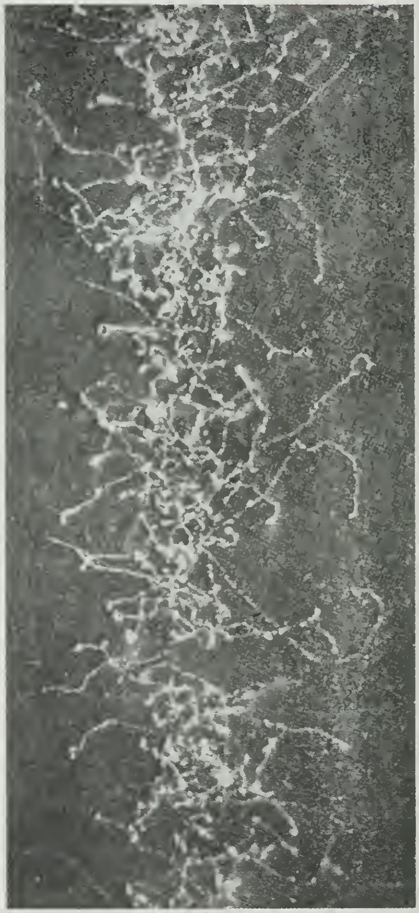
The beta particle is an electron. The alpha particle is a helium atom stripped of two electrons. As the alpha particle slows down it picks up two electrons from some neighboring matter, and it is then an ordinary helium atom, and emits the same spectrum as helium.

Radiants may also emit gamma rays, which are closely analogous to Röntgen rays and are doubtless similar to light, consisting of ether undulations, but with wave-lengths several hundreds of times shorter than those of light.

Much theoretical deduction was confirmed when C. T. R. Wilson photographed illuminated ions, mist-ladened, marking the tracks of electrons, which had been hurled forth by a pencil of Röntgen rays (Fig. 1).

As Bragg surmised, the Röntgen rays did not ionize the gas directly. They ejected high-speed electrons, and these electrons, passing through the molecules, drove some low-velocity electrons from the latter, thus giving rise to pairs of ions. The beautiful photographs of C. T. R. Wilson showed this very clearly. They bring us, moreover, abruptly face to face with one of the profound mysteries in physics.

Fig. 1.



The Röntgen rays are caused by the quick stoppage on a target of fast-moving electrons in the Röntgen tube. These rays, like light, must spread outwards with the flux of energy decreasing by the law of inverse squares. Yet when these diverging rays strike some one out of a vast number of molecules there is ejected an electron with a speed almost equal to that of the primary cathode rays. The ejection may take place, moreover, many metres away from the tube. No explanation of this anomaly is forthcoming. The energy cannot come from the atom, for when the *intensity* of the rays is increased there is a corresponding increase in the *number* of ejected electrons. When the *frequency* of the waves of the Röntgen rays is increased there is an increase in the *kinetic energy* of the projected electrons. Indeed, we may write approximately that

$$\tfrac{1}{2}\, mv^2 = hn$$

where the left member is the kinetic energy of the electron, n is the frequency of the X-rays, and h is Planck's number equal to 6.6×10^{-27} erg second.

This interesting relation represents a fact, but explains nothing and itself demands as much explanation as the initial difficulty.

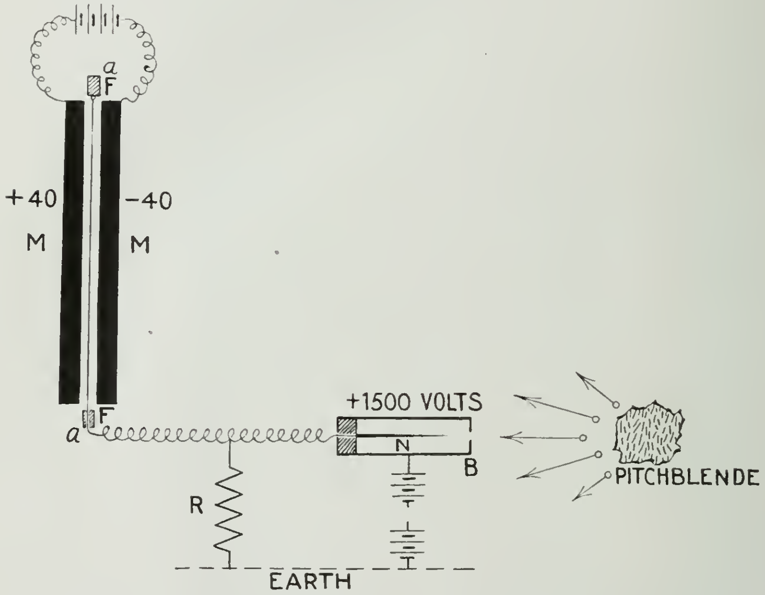
In conversation W. H. Bragg once gave to me a striking analogy. Let the moon represent the source of X-rays, and the moonlight, shining on the earth, represent the Röntgen rays falling on a body. Just as the Röntgen rays eject here and there a high-speed electron, so the moonlight would have to cause something about the size of a pea to leap out with great velocity, first one, say, from Siberia, then one from South Africa, next from New Guinea, and so forth. Violent and very local action produced by a uniform and homogeneous radiation!

The Counting of the Alpha Particles.—Before C. T. R. Wilson had taken the photographs already described, Sir Ernest Rutherford had devised an apparatus which enabled him to detect the alpha particles entering, one by one, into a testing chamber in such a manner that their number could be counted. In this way he was able to deduce that the alpha particle had a charge twice as great, but opposite in sign, to the charge of an electron; that a gramme of the metal radium expelled 3.57×10^{10} alpha particles per second, and he found accurate values for other fundamental constants.

For the detection of the individual alpha particle this eminent physicist was, with a pretty humor, justly awarded the Nobel Prize for chemistry.

The Detection of the Individual Electron.—The alpha-ray detector was altered and improved, and a few years later Geiger was able to report that he had succeeded in detecting *single* electrons entering a suitable orifice in his new testing chamber. As I had, owing to the kind help of the secretary, Dr. Owens, the pleasure of performing experiments with this type of apparatus at The Franklin Institute, it may be well to give a fairly full description of it.

Fig. 2.



B is a hollow brass cylinder (4 x 1 cm.) with a small hole in the end (where the electron enters), Voltage + 1500. *N* is a fine, sharp, clean needle with its point about 8 mm. from the hole. *R* is a high resistance, about 100 megohms, of xylol and alcohol in a glass U tube. *FF* is a fine, silvered, quartz fibre between two metal plates 8 mm. apart, 15 cm. long, charged to low opposite voltages.

When an electron, say a beta particle from a radiant, enters the small hole in the testing vessel *B*, it approaches a point *N* which is almost sparking to the high-potential chamber (Fig. 2). The ions produced by the particle, particularly the negative ions, are urged forward with a very high velocity by the intense electric field, and these ions produce more ions by collision. It is as though a temporary minute spark passed, so that the needle leaps up from zero to 36 or 40 volts. As the needle is connected to the quartz fibre *FF* this latter is at once charged, and, being between charged plates, is deflected. A stable state is swiftly re-established, owing to the high resistance R, and the trap is reset to show the next electron. The movements of the quartz fibre are seen when projected on a white screen. With this apparatus many beautiful experiments can be shown, such as the range of the alpha particles from polonium; individual alpha particles passing through a pinhole in paper; the reflection or scattering of rays from lead or from aluminum, in which case the lead is the more effective; the long-distance effect of the gamma rays and their highly-penetrating nature. But the most excellent and impressive sight is that of a piece of pitchblende, just as it came from the mine in Bohemia, continually expelling alpha and beta particles into the surrounding air. Remember also that it is capable of continuing to do so for a period exceeding one thousand million years.

On the Nucleus of Atoms.—Sir Joseph Thomson had suggested an atomic structure having a number of electrons revolving in concentric circles within a vague entity consisting of positive electricity. Sir Ernest Rutherford, working with Geiger, found that when alpha particles bombarded thin gold leaf the great majority of the particles passed through, but about one in every eight thousand returned on the side of entry. He came to the conclusion that the returning alpha particle had encountered a highly-charged nucleus. Working out this idea on the basis of Newtonian mechanics, he concluded that the nucleus was small in its effective dimensions, but that it had a charge equal to about one-half of the atomic weight of the atom. This idea was amply verified by a long series of experiments, and it fitted well with results obtained by Barkla, who, stimulating matter with Röntgen rays, obtained evidence that an atom contained electrons to a number about half that of the atomic weight.

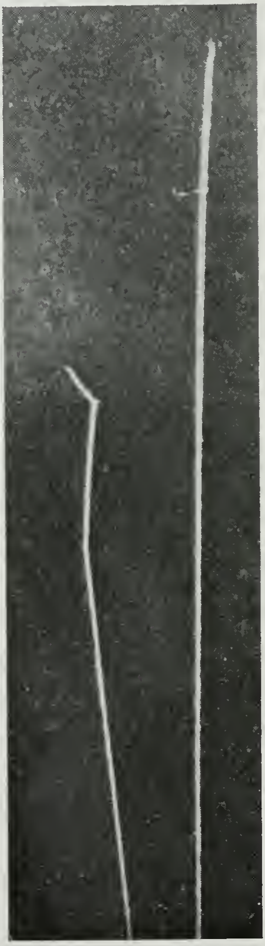
Putting these results together, we obtain something resembling a miniature solar system, with the minute central body consisting of a large positive charge, and in concentric surrounding rings are electrons revolving like planets,[2] but perhaps with several in each ring, and so adjusted that their total charge, which is negative, balances the positive charge on the nucleus.

The Alpha Particle and Hydrogen Nucleus.—In one of Wilson's photographs of the track of an alpha particle (Fig. 3) there appears, near the end of the path, a small projecting spur, which he explained as due to an atom of an air molecule, struck by an alpha particle, receiving sufficient velocity to ionize the air for a short distance. It immediately occurred to Rutherford that if an alpha particle passed through hydrogen, then the light hydrogen atom, or rather its nucleus, would be projected, not merely to a greater distance than the nucleus of the oxygen or nitrogen

---

[2] There is, however, no direct experimental evidence that the electrons revolve. They may vibrate about stable positions.

FIG. 3.



atom, but to almost four times the distance of the alpha particle itself. This forecast was verified by Marsden, using a zinc sulphide screen, when the scintillations due to the hydrogen nuclei were seen at a range nearly quadruple that of the alpha particles. This important verification has placed the theory of the nucleus on a foundation which excludes doubt as to its reality.

The Beta and Gamma Rays.—Another photograph was obtained by Wilson showing the long range of the electron expelled by incident gamma rays. In air at atmospheric pressure this secondary beta particle will traverse more than a metre. As will be seen later, the gamma rays are electromagnetic disturbances having a minute wave-length, even compared with light waves; and a correspondingly high frequency. The kinetic energy is, as with Röntgen rays propelling electrons, again approximately equal to h times the frequency, when h is Planck's constant. The mechanism by which these phenomena occur is unknown, whether we consider electrons projected by ultraviolet light, Röntgen rays, or gamma rays.

Planck's Constant.—When in a reflecting enclosure there is a heated body and, necessarily, ether, the former has a limited number of degrees of freedom, and the latter an unlimited number. It may, therefore, be expected that, as theory appears to indicate, the energy of the body would decrease and that of the ether increase, particularly towards vibrations of the shorter wave-lengths. Experiment proves that this does not occur, and that the distribution of energy is utterly different from that which Newtonian mechanics demands. Planck found himself able to explain this distribution only on the supposition that energy could leave the oscillators in the body by exact *quanta,* the magnitude of which was in each case proportional to the frequency of the oscillator, or equal to hn. Shortly before his death Poincaré thoroughly investigated this hypothesis and concluded that an explanation on the basis of Planck's hypothesis was inevitable, and that no other view was in accordance with observed radiation phenomena. An able summary of the whole subject has been given by Jeans in a report published by the Physical Society of London.[3] We have, therefore, a unique situation in physics. The quantity h has been introduced and its magnitude determined without our having any approximate idea of what *h* represents. To the student of radio-activity it is the ratio of the number of units of the kinetic energy of the projected electron, divided by the frequency of the incident electromagnetic disturbance, or possibly by some exact multiple of that frequency.

---

[3] "Report on Radiation and the Quantum Theory," by J. H. Jeans, *The Electrician* Printing Company, Fleet Street, London.

Röntgen Rays and Crystal Reflection.—It was foreseen by Laue, at a time when the potentialities of Röntgen rays appeared almost exhausted, that these rays would be scattered in a definite direction from any set of orderly parallel planes in which the atoms of a crystal are arranged. An analogy may be useful. If troops with fixed bayonets are not drawn up in rank the sunlight reflected from the bayonets will give to a spectator a glint here and there. In well-dressed ranks, however, a spectator will in some positions see no reflections, but in other positions, when the angles of reflection and incidence are equal, he will obtain a powerful flash from all the bayonets in all the ranks.

Professor W. H. Bragg and his son have developed this method and obtained information as to the distribution of atoms in various crystals, the distance between the atoms, and the wave-lengths of the Röntgen rays. He has himself summarized this work in an article published recently in *Science* (December 4, 1914).

Crystal Reflection of Gamma Rays.—The gamma rays have been reflected from the regular layers of atoms in a crystal in a manner quite similar to that employed with Röntgen rays, a radiant taking the place of the X-ray tube. In this way Rutherford has found that the wave-lengths of the most penetrating gamma rays, glancing from the crystal face at 42′, is about 0.7×10^{-9} cm. This is the smallest wave-length known, but the phenomenon may as justly be attributed to an electromagnetic disturbance in the ether as a radiotelegraph wave with a length of several kilometres.

It is interesting to note, in some papers of Rutherford's, how he appears to use language and ideas which are at present totally irreconcilable. I am not venturing to criticise this, for the statements do indeed represent the facts. At one time Rutherford is speaking of "a gamma ray," thus suggesting *linear* propagation of energy, and at another time he is discussing the wave-length of a gamma ray with a meaning applicable to ordinary light radiation and therefore involving an expanding wave front. We are reminded of Newton's troubles in explaining diffraction by a corpuscular theory, and concluding that light has an "eel-like" motion.

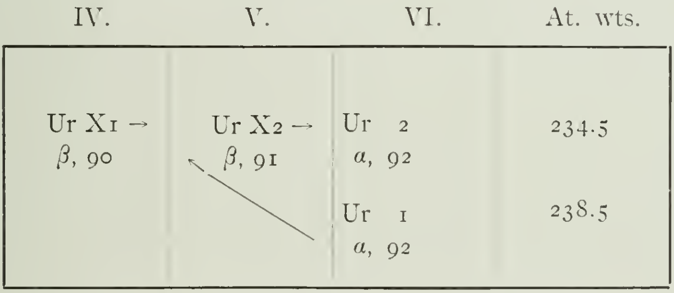
Atomic Number.—Since the positive charge on the nucleus of an atom is about half the atomic weight, and since that charge is necessarily a whole number when expressed as a multiple of the magnitude of the charge of an electron, it has been suggested by van den Broek that there is a fundamental and important number connected with every element, known as the atomic number. This number is possibly the place of the element in the periodic table (H 1, He 2, Li 3, Be 4, Bo 5, C 6, etc.). This theory has had strong confirmation from a series of experiments by Moseley. He exposed most of the elements to the bombardment of electrons in a vacuum tube, these elements forming, in turn, the anticathodes of a Röntgen tube. The natural or characteristic radiations of the elements were reflected from a crystal surface, and the frequencies of the vibrations were thus determined. After a correction for the outer electrons, it was found that in every case the frequency was proportional to the square of an integer which was identified with the atomic number. According to Sir Joseph Thomson, when an atom has, suppose, three rings of revolving electrons, the outer ring is that influenced by ionization and is investigated by spectrum analysis, the inner ring is connected with the penetrating, or hard, or K series of characteristic Röntgen radiations, and the middle ring with the less penetrating, or soft, or L series. To the nucleus we must look for the main effects of mass and inertia, and gravitational attraction, and, when they exist, for the radio-active transformations and expulsions.

Bohr's Theories.—It has been pointed out that when a single electron revolves round a unit charge nucleus, as in the case of hydrogen, that by electromagnetic theory there should be a continued stream of energy radiated away into space, necessarily demanding that the revolving electron would lose speed and fall into the nucleus. To overcome this and similar difficulties, Bohr has suggested a theory of stable states, non-radiating, with the angular momentum an exact multiple of $h/2\pi$, where h is Planck's constant. When the multiple is, for reasons unknown, diminished by unity, the electron abruptly changes from the old stable state to the next stable position, and in doing so radiates away an exact quantum such as Planck first conceived. It must be admitted that these ideas appear at first highly imaginative, and they might well be ignored but for the remarkable degree of success which they have already achieved. Notably he foretold the existence of certain lines in the ultra-violet spectrum of hydrogen, and these were subsequently discovered by Lyman. He identified lines found by Paschen in the infra-red, and also obtained an excellent numerical verification between his theory and the value of the constant of Rydberg which links up the spectral series of various elements. Perhaps the most interesting suggestion is that lines seen in the spectrum of certain stars may be assigned to hydrogen in a state of extreme tenuity, so that the electron revolves in a greatly-enlarged orbit about the nucleus, a state which it is impossible to imitate in the small vessels of our laboratories.

Valency Law of Radiants.—A band of chemists who have made a careful study of the properties of the radio-elements have succeeded in the discovery of an interesting law which removes the difficulty of finding places in the periodic table for all the radiants, about thirty-seven in number. A full account of this work is given by Soddy in "The Chemistry of the Radio-elements" (Longmans, Green & Co., 1914).

Briefly, it has been found that when a radiant expels an alpha particle, thus reducing the charge on the nucleus by two electronic units, there is a corresponding change of valency, say from tetravalent to divalent, so that the new product is two columns to the left in the periodic table, while the decrease of atomic weight is four. When a beta particle is expelled there is no effective change of atomic weight, but the nucleus charge or atomic number has increased by one, since the loss of a negative is equivalent to the gain of a positive electronic unit charge. The subsequent product is now found one column to the right in the table, relative to the parent element. Two elements with different atomic weight, but with the same nucleus charge, may find themselves in the same place in the periodic table, and are known as isotopes. Such elements have chemical and physical properties so similar that they are at present deemed inseparables or non-separables. As an example, it is possible to obtain radium D as it forms from the disintegration of radium C. If this radium D is mixed with lead, separation becomes impossible, because their chemical properties are identical. This theory has already achieved a notable success. In the early days of radioactivity Sir William Crookes obtained uranium X by chemical separation from uranium, and it was shown that it was a linear descendant. The uranium was found to eject two sets of alpha particles of different ranges, so that it was presumably two radiants and not one. The law above described suggested both the presence of an undiscovered radiant and also its chemical properties. This substance, uranium X2, or brevium, for it is short-lived, was quickly discovered.

The conclusion arrived at is set forth in the following typical scheme, where uranium 1 and uranium 2 are inseparables or isotopes, with atomic weights differing by 4, but with atomic numbers and valencies identical.



The Positive Electron.—In the early days of the electron theory it was not unnaturally supposed that the positive electron was similar in general character to the negative electron, the two, of course, neutralizing one another. The diligent search of many eminent physicists has failed to obtain evidence of any such entity, and in no case has a positive electronic charge been observed except accompanied with a mass of atomic dimensions. Sir Joseph Thomson has found that the hydrogen atom, alone of the elementary atoms, never loses more than one electron. It has been suggested by Sir Ernest Rutherford that the long-sought positive electron may, in fact, be the nucleus of the hydrogen atom, and, in that case, that its mass would be 1800 times as great as the mass of the negative electron. If this mass is electromagnetic in character, it must vary inversely as the radius, so that the positive electron would have a sphere of action extremely minute, even compared with the negative electron. The radii of the three spheres would then be of the following orders:

Atom, 10^{-8} cm.
Electron, 10^{-13} cm.
Positive electron, 10^{-16} cm.

It is clear that the investigation of the inner constitution of the electrons will offer formidable difficulties to future generations of physicists.

CONCLUSION.

There are generally not a few men of small intellect or foresight who ask, "What is the good of these philosophical discoveries?" Such is not the attitude of those who are engaged in the practical work of applying scientific discoveries to the benefit of mankind. But, apart from inventions, so often misdirected to the destruction rather than the elevation of the human race, it is well to urge continually the high aim of the search for truth for its own sake, wheresoever it may lead us. It may be noted that the discoveries set forth in this brief summary have been achieved by savants in the western half of Europe, and it may be asked if the education in the New World is at the present time sufficiently thorough, imaginative, and philosophical. In any case, the future improvement of mankind is likely to arise from education in the sense of development of knowledge, character, and principles, rather than from the acquisition of wealth, or by the multiplication of material resources.

Magnetization in Rapidly-oscillating Fields. H. Rohmann. (*Ann. d. Physik.*, xliv, 6, 817.)—A magnetized bar is more or less demagnetized when placed in an oscillating magnetic field of which the amplitude continuously decreases. On the other hand, an unmagnetized bar may be magnetized by means of the discharge of a battery of condensers. The magnetism produced depends partly on the amplitude of the alternating magnetic field and partly on the manner in which the field diminishes to zero. Further, the magnetizing action of a damped vibration changes qualitatively even when its course is changed by a definite but relatively small amount. Experiments are described showing the effect of the superposition of two damped sine oscillations which give rise to more complicated vibrations.

THE MODERN SUBMARINE IN NAVAL WARFARE.*

BY

R. H. M. ROBINSON,

Managing Director, Lake Torpedo Boat Company, Bridgeport, Conn.

When I accepted the Institute's invitation to address you, war had not been declared, but since its declaration the history of the submarine in warfare has been in the making, and so much has happened and was likely to happen, bearing on my subject, that I postponed preparing any paper until the last minute, and so, I fear, should apologize for it.

As an actual designer and builder of submarines I am fairly new at the game, though I have to draw on, the accumulated experience and advices of my colleague, Mr. Simon Lake, one of the pioneers in the practicable submarine field.

Most of my early experience in the field of design and construction was with surface warships, with which I may claim reasonable familiarity, having, during an eight years' tour of duty as assistant to the chief constructor of the navy, supervised the design of every dreadnought now in commission in our service and half of those now building, together with numerous other surface craft of all types.

It is, therefore, on my knowledge of the vulnerability of the dreadnought type to submarine attack as much as on my knowledge of submarines that I must base my right to talk to you.

In the beginning permit me to say that I am not one of those who believe the submarine a cure for all naval ills, or that it will supplant surface warships.

I am, however, and have always been, a strong advocate of the submarine as one of the most powerful naval weapons of defence, and as possessing offensive qualities which, in the fulness of time and with the development of engineering science, cannot be minimized.

The wording of my subject might imply that I expected to pose as a prophet, but I should prefer, if I may, to show you certain facts and in most instances to allow you to make your own prophecy.

---

* Presented at the meeting of the Mechanical and Engineering Section held Thursday, December 10, 1914.

Admiral Sir Percy Scott, of the Royal Navy, in his now famous letter to the *London Times* of June 5, this year, took the strongest possible stand for the submarines and, incidentally, against the battleships, concluding his letter with the statement: "In my opinion, as the motor vehicle has driven the horse from the road, so has the submarine driven the battleship from the sea."

Coming as it did from one who had contributed so much to the development of the battleship offensive power, this letter made an enormous impression, though I cannot but believe that Admiral Scott stated the case somewhat more strongly than was justified or than he himself really believed.

What may very well be the case is that the effect of the submarine will be to reduce the rapid growth in size and expense of the dreadnought type, now reaching to almost unbearable amounts.

The menace of the submarine arises, first from her invisibility, and, second, from the fact of the difficulty of providing against the damage which will result from a blow from the weapon she carries.

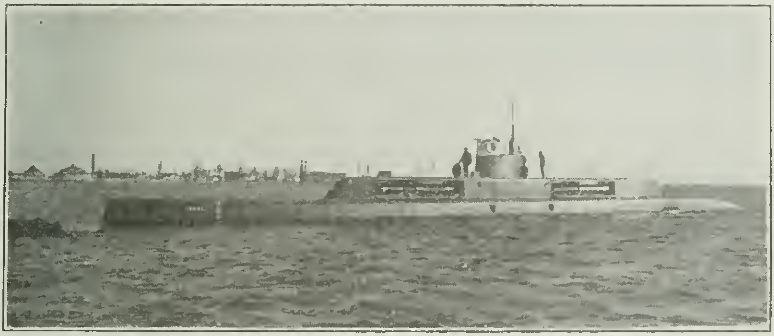
Sir John Biles, LL.D., in a recent paper before the British Institute of Naval Architects, says:

"There can be only two forms of defence: first, the destruction of the submarine by other vessels, submarines or others; second, the protection of the bottom of the surface ships from the effect of under-water attack. The first, the destruction of the submarine, is obviously not the work of a battleship or large cruiser, but must be left to some vessel of the same order of size as the submarine. This destruction must be sought on the surface when the submarine is not submerged, for it seems improbable that a submarine will be able to chase another effectively under the water. In any case, the submarine will be dangerous to the large surface ships until it is destroyed, and, as the means of destruction are not yet certainly at hand, the question of effectively protecting the battleship against under-water attack seems to be deserving of consideration, unless some one is ready with a real reply to the submarine."

A great deal of attention has been given by naval architects to providing, in the dreadnoughts, protection against the automobile torpedo, with astonishingly small success up to the present time.

I personally struggled with this question for a good many years, and I believe, without conceit, that the United States has to-day as good a solution as has yet been obtained, but even that is by no means perfect.

For a ship at anchor a reasonable protection against the possibility of damage from the automobile torpedo may be obtained by the use of torpedo nets, although the development of the net cutter, attached to the torpedo's nose, has made even this uncertain. It is almost impossible to use a torpedo net on a ship under way. In the first place, it enormously decreases the speed and handiness and enormously increases the fuel consumption of the vessel wearing the net, and, in the second place, the mere fact that the vessel is under way causes the bottom of the net to rise to the surface and thereby largely does away with the advantage of the net.



Submarine (*Seal*) G 1, U. S. Navy (Lake type).

This being the case, the only remaining possibility is to include within the structure of the vessel itself provision against damage by attack from a torpedo. Unfortunately, it is much easier to increase the power of the torpedo than it is to increase the defensive protection built into the hull of the dreadnought, with the result that, if any given class of surface ship has protection against the then existing torpedo, it is fairly easy to vitiate the value of this protection by increasing the power of the torpedo.

Briefly, the provisions which may be embodied in the design of a ship against the damage of the torpedo comprise under-water armor, additional compartmenting, and compressed-air installation for localizing the inflow of water. The under-water armor, on the face of it, looks like a good solution of the problem, but, as a matter of fact, it is of very little use to put under-water armor on the external hull of the ship. A torpedo explosion has a crushing effect, which results in tearing the riveted joints. The rivets seem to be attacked in detail, and an increase in the amount of metal applied externally does not do away with the necessity for riveted joints, and, if under-water armor were put on the ship in the same manner as the above-water armor, there would be *no* connection at the joints, since the armor above water is simply plastered up against a backing plate.

Careful and minute compartmenting, of course, covers a large number of possibilities, but provides only against the damage done by the torpedo in localizing the effect of the damage.

The compressed-air installation is a means of preventing water entering the body of the ship in too large volumes as the result of any damage done by a torpedo. It has to be specially applied, utilizing what is called the " backing up " method, using pressure in the adjacent compartments of varying degrees so as not to damage the ship's structure by the air-pressure.

The best solution of the problem is a combination of the three methods referred to above:

Proper compartmenting—and by this I mean something different from the time-honored system in use in the older days—under-water armor not located on the external hull of the ship and so designed as to give a maximum strength to the structure of the ship, and a graduated compressed-air installation for checking the water after it gets into certain compartments which cannot be prevented.

There are several essential features in designing a surface ship and in providing these anti-torpedo protective features which must be looked out for. The principal among these is the effect on the longitudinal or transverse trim of the vessel, from water getting into one or more compartments. The question of longitudinal trim is ordinarily not as important as transverse, and provision may be made, and has been made, for balancing transverse trim or list by admitting a similar amount of water on the opposite side to that damaged. This course results in a greater sinkage and consequent reduction in speed and safety of the vessel, but, when a balancing system is properly arranged in combination with the defensive means mentioned above, it should probably result in the ultimate salvage of the ship, although her value as a fighting unit after the damage from the torpedo would probably be little or nothing for the time being.

The British cruisers *Aboukir, Cressy,* and *Hogue,* which were sunk by the German submarine *U*-9, were, of course, not ships of the most modern type. They, however, represent a very excellent type of ship of some fifteen years ago, and the fact that each of them sank as the result of a blow from a single torpedo indicates plainly enough the fact that a ship of very little age soon becomes practically out of it when subject to the danger of submarine attack.

The more recent sinking of the dreadnought *Audacious* brings this thought more forcefully to our minds.

The submarine, as you know, is not at all a new idea; in fact, some very excellent conceptions of submarines are quite old. Any one desiring to investigate this fact has but to read the interesting and complete work on " Submarine Navigation," by Allen W. Burgoyne, who rehearses the various types of submarines projected or undertaken by all manner of people since before the beginning of the Christian era.

The list of inventors includes men of all nationalities and from all walks of life, doctors, clergymen, lawyers, military men, and mechanics.

Some of the projects were absurd, many were never undertaken, but others had excellent ideas, and were perfectly practicable, except in one essential particular: a proper prime mover for propelling and auxiliary power.

The early boats were, of course, propelled by hand, no other power being then known, and it takes little imagination to understand how laborious this was and how little speed or control could be expected from a craft so propelled.

It was not until steam had been used as a motive power in surface ships for many years that a really operable submarine was produced, and not until the development of the internal-combustion engine and the storage battery that the submarine became the well-developed instrument that we know to-day.

Strangely enough, there has been of late a return from the internal-combustion engine to steam in certain instances for surface propulsion, but so far the storage battery holds undisputed sway as a source of power for under-water work.

The submarine at present must carry two entirely distinct and separate sources of power, one for surface work and one for submerged work, and the storage battery per unit of power is very heavy.

I have kept before me for years a sign that reads: "The man who says a thing is impossible is apt to be interrupted by somebody doing it." So I shall not say that any means of under-water propulsion other than storage batteries is impracticable, but at the present time no other practicable means is apparent, and it is this very fact that is the greatest restriction confronting the submarine designers and builders.

Submarine *Narwhal*, U. S. Navy (Holland type).

The essential features of any submarine from a military point of view are surface speed, surface radius, submerged speed, submerged radius, and armament.

Surface Propulsion.

The early successful submarines had gasoline engines. These were later superseded by heavy oil engines of the Diesel cycle-first, four-cycle engines, and, more recently, two-cycle engines, of which several types have been used. None of these can be said to be perfect yet, but great improvements have been made and are still making.

The high pressures and temperatures that occur in the Diesel engine result in stresses that are serious, and the high speed and comparatively light construction that must be obtained in submarine engines give a chance for trouble that might not exist in a slow-going installation.

Mr. J. T. Milton, in a paper read before the British Institution of Naval Architects in April, 1914, says:

"Diesel engines are broadly divided into two classes, viz., the two-stroke and the four-stroke cycle, respectively. In both types a cylinder full of air at atmospheric pressure is compressed by the piston till at the top centre its pressure becomes about 500 pounds per square inch. The compression raises its temperature to about 1000° F. At this instant a small quantity of oil fuel is blown into the very hot high-pressure air by means of a blast of air at a still higher pressure. The arrangement of the fuel valve and its gear is such that the oil is broken into a fine spray, and its admission lasts only for the short time which it takes for the piston to perform about one-tenth of its downward stroke. During this short time much of the oil becomes burned in the hot air. The heat generated by the combustion raises the temperature considerably, and, consequently, must increase either or both the pressure and the volume occupied. What is aimed at is that the combustion should proceed at the critical rate which would permit the increase of volume occupied due to the motion of the piston and the increase of temperature to be so balanced that the pressure will remain constant until the whole of the oil has been burned. After this the expansion of the hot gas will still further push the piston down, and the pressure will rapidly decrease. The temperature will also rapidly fall, mainly through the conversion of some of the heat into work, but partly also by some of it being conveyed into the cylinder surfaces, these being kept comparatively cool by water circulation. The maximum temperatures actually attained in the cylinders are very high, approximating, in some cases, to nearly 3000° F. It is these excessively high temperatures which occasion some of the special difficulties of Diesel engines. It is necessary to keep the rubbing surfaces of the metal, which are exposed to the hot gases, sufficiently cool to permit of their retaining their lubrication, and it is also necessary to prevent all the metal with which the heat comes into contact from becoming so overheated as to damage its strain-resisting properties.

"The foregoing remarks apply to all types of Diesel engines. In the case of the two-stroke cycle engine, just before the completion of the expansion stroke, the piston uncovers some ports in the lower part of the cylinder walls leading into an exhaust passage, and a considerable portion of the hot gas escapes, the pressure falling to about that of the atmosphere; then in some designs some valves in the cylinder cover are opened, and fresh air supplied by the scavenging pump at a pressure of about 4 pounds per square inch blows out the remainder of the burnt gas, leaving the cylinder full of fresh air ready to be compressed by the return stroke of the piston. In some designs the exhaust ports are placed on one side only of the lower end of the cylinder, and on the other side similar ports, also opened by the travel of the piston, but at a somewhat later instant, admit the scavenging air. In these cases the tops of the pistons are curved to direct the entering air upwards, and it is claimed that the scavenge air travels right to the top of the cylinder and entirely displaces the burnt air. In these latter designs the scavenge valves and the gear for working them are dispensed with, and, consequently, the engines are to some extent simplified."

Storage Battery Plant.

The safety and success of the attack of a submarine depend to a great extent on her ability to approach the enemy while submerged and to remain submerged for a long time. In a high-sea engagement the enemy's fleet may naturally be assumed to be under way at some speed, so that the development of the sea-going type, to which some reference will be made later, will logically include some increased submerged speed and considerably increased submerged radius for manœuvring in the vicinity of the enemy for a long period.

Increased submerged speed and increased radius of action submerged will make the batteries proportionately larger than are at present used.

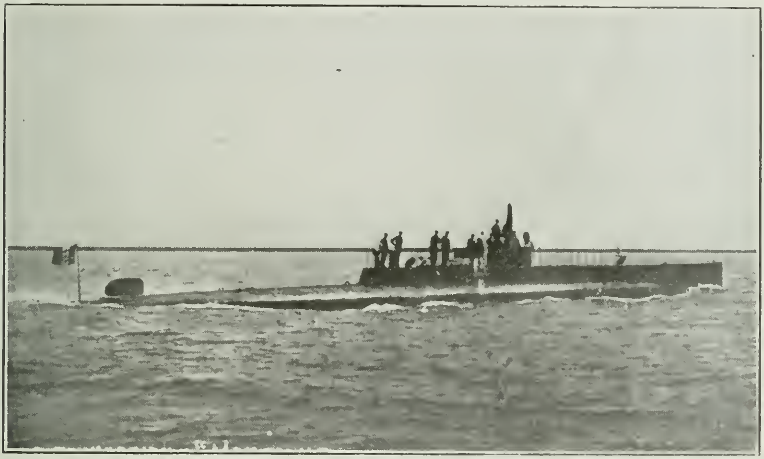
In the case of the sea-going type of submarine the design of the storage battery requires study in order to get the battery best adapted to obtain the maximum speed submerged and the greatest radius of action along with a reasonable length of life.

Storage Batteries Used on or Proposed for Submarine Boats.

There are two general types of storage batteries in more or less general use at the present time, namely:

Class A—The lead type, using as electrolyte sulphuric acid of a density of about 1.230.

Class B—The iron-nickel type, using as electrolyte caustic soda, known as the Edison battery.



Submarine *Nautilus*, Italian Navy (Bernardi type).

Of these, so far as I know, the lead battery is the only one that has yet been used in submarines, newspaper stories to the contrary notwithstanding.

The lead type (Class A) uses peroxide of lead as active material on the positive plates, and spongy lead as active material on the negative plates, immersed in an electrolyte of H_2SO_4.

This general type embraces three distinct methods of manufacture of the individual plates, known as the "Plante" or electrochemically formed plates, the "Pasted" type of plate, and the "Ironclad" plate, which is a particular construction of a "Pasted" type of plate.

(*a*) The "Plante" (sometimes called "High surface") plate is made of a fine grid which is either cast, grooved, or spun in such a manner as to produce a very large superficial area available for electrochemical action. The grid is then subjected to an electrochemical process whereby the lead on the surface is reduced to peroxide of lead for the positive plates and spongy lead for the negative plates. On submarines the " Plante " positives are used in combination with " Pasted " negatives wherever the " Plante " plate is used.

(*b*) The " Pasted " plates have grids cast of lead with a small percentage of antimony, and usually consist of a frame supporting a network of meshes into which the " Paste " from which the active material is formed is pressed, and then reduced electrochemically to peroxide of lead in the case of the positive plates and to spongy lead in the case of the negative plates.

(*c*) The " Ironclad " plate has the frame for supporting the active material made of perforated hard-rubber compound, consisting of a series of finely-slotted, hard-rubber tubes arranged side by side vertically in a support frame of hard rubber. An antimony lead grid for collecting the current is provided with lead rods running into the centre of the tubes for the full length. The tubes are filled with the ingredient for forming the active material—mostly red lead (PbO)—and this is then reduced to peroxide of lead, electrochemically, thus forming a positive plate.

The ordinary " Pasted " type of negative is used in combination with this plate in making up the cells.

The Edison storage battery (Class B) uses nickel oxide as active material in the positive plates, and iron oxide in the negative plates, immersed in an electrolyte of caustic soda.

The positive plates are made up of perforated steel tubes containing nickel hydrates for forming the active material, the tubes being carried in a steel frame or grid.

The negative plates consist of perforated steel envelopes containing iron oxide. The envelopes are made of two perforated steel sheets forming pockets between them for holding the active material.

General Comparison of Types: Lead type. *vs.* Edison type.

(*a*) Discharge voltage.

The average discharge voltage per cell for the lead battery at the three-hour rate of discharge is generally about 1.84 volts per cell for the " Pasted " type of plates, whereas the average voltage for the Edison battery at the three-hour rate of discharge is, I believe, in the neighborhood of 1.2 volts per cell.

Therefore, to obtain the same average voltage during discharge given by a lead battery of 120 cells, there should be required 192 Edison cells.

(*b*) Space required.

In ordinary submarine design the floor space or projected area occupied by the battery is usually more important than the cubic contents. The space required for the Edison battery has until recently been more than that required by the "Pasted" type of battery for the same power.

(*c*) Weight.

The weight of the Edison battery is understood to be greater than the weight of the "Pasted" type of battery for the same power, though as some of the special requirements necessary with the lead battery, such as lead lining of battery spaces, are not necessary with the Edison, all this difference in weight may disappear.

(*d*) Efficiency.

The efficiency in ampère-hours for the lead battery is approximately 0.9 and for the Edison approximately 0.75. The efficiency in watt-hours for the lead battery is approximately 0.76 and for the Edison approximately 0.55. Gasing occurs much earlier in the Edison battery cell during charge, and the potential drop during discharge is greater for the Edison cell than for the lead type of cell.

(*e*) Life.

The life of the Edison battery is greater than that of the ordinary "Pasted" type of cell, but the manufacturers of the "Ironclad" types now claim a life about equal to that of the Edison battery.

(*f*) Cost.

So far the cost of the Edison battery is far greater than the lead type, though, with its greater life, the greater cost may be claimed to be justified.

In designing a purely military weapon such as the submarine it is a grave question in my mind whether durability must not definitely be sacrificed for capacity, unless both can be gotten.

A large radius and speed are more desirable than length of service, which can be provided for by providing more boats, so that when one is withdrawn another may be put in its place, or by providing spare batteries for the boats in service.

Electric Propulsion on the Surface.

Owing to the mechanical difficulties involved in large reversible Diesel engine plants, it may be found advisable to design for a purely electrical propulsion—surface as well as submerged—using Diesel-driven generating sets, or turbine-driven generating sets driving motors on the surface. The present difficulty in the way of such an installation is the size of direct-current motors required for constant duty on the surface.

Submarine *Atropo*, Italian Navy (Krupp type.)

To save space and weight, voltage up to 500 volts would suggest itself as feasible, or, as a compromise, to use 500 volts for surface running and 250 volts when running submerged, which would involve practically the same voltage as at present used on submarines.

The electric propulsion would involve one or more direct-current generating plants, and the propeller shafts would be supplied direct from the generators for surface running and from the storage battery for submerged running. The speed control obtainable from such an equipment is ideal.

Some propositions have been advanced for obviating the necessity of a duplicate propelling plant, utilizing the surface cruising engines also for submerged work. One of the most prominent of these, up to date, is the Del Proposto system, proposed by a Belgian engineer of that name.

To quote in part from a paper by Mr. Del Proposto, the system is based on the following principles:

"The compressed air can first be regarded as a fluid with a potential power due to its pressure, and then as a chemical composition. Thus it can serve twice for producing energy: first, in a compressed-air motor, and then as feed for an internal-combustion motor. This twofold use of the same air for producing energy leads, evidently, to a reduction in air consumption per horsepower-hour and a given lesser quantity of air to be stored on board for developing a given quantity of energy, and therewith also a reduction in the required weight of air tanks. Thus we come logically to the following conception of the boat, viz.:

"A boat or submarine diver of which the propulsion on the surface is ensured by an internal-combustion motor, which, during such run, can also actuate a compressor which stores air at high pressure in the tanks. During under-water runs the compressed air, reduced to a suitable compression by means of a reducer, passes first through a compressed-air motor, which need be no other than the compressor before mentioned, if its construction allows it, or one or two cylinders of the internal-combustion motor. Then the air is drawn up by the internal-combustion motor, which under water continues working exactly as on the surface. The air which has escaped from the compressed-air receptacle and drawn up by the internal-combustion motor remains in a closed vessel, but if we take note that this air has not lost its chemical qualities nor its composition, and, therefore, can well serve for the breathing of the crew, it is suitable to let it first escape inside the boat, whence it is drawn by the internal-combustion motor.

"In arranging the escape openings of the compressed-air motor on one of the ship's ends at the side where the crew usually is, and the suction of this motor at the opposite end, we establish inside the boat an artificial air current, continuously ensuring strong ventilation.

"It may be noted that, the escape passage of the compressed-air motor and the suction of the internal-combustion motor taking place in the same connecting tubes, it would be necessary to establish there a receptacle of great capacity, which would serve as regulator, intended to avoid the pressure variations at the entry of the internal-combustion motor. In the above-indicated arrangement the whole inside of the boat acts as intermediary tank, and, consequently, the unchangeability of the pressure could be easily maintained. Seeing that the air which serves for the production of energy is used for ventilation of the boat, we have thus an automatic renewal of air without recourse to special apparatus."

I believe the construction of a boat embodying these principles was undertaken, but I am of the impression that its advantages were not all that had been expected. It serves, however, to indicate a possible line of solution, and one which would be desirable if it could be attained.

There have recently come forward several propositions of a somewhat different character, but a proven installation has not yet been produced.

Propellers.

One of the most difficult problems to solve in connection with the design of a power plant for submarines—in fact, a problem without exact solution—is the design of a propeller suitable both for surface and for submerged navigation. There are two conditions to meet, which call for two distinct propellers. Broadly speaking, the first condition is to obtain a certain speed with a certain resistance to propulsion on the surface; submerged, the speed may be the same, but the resistance has increased, because the body to be pushed through the water has increased in volume and has changed shape. It is impossible to have two distinct propellers, and a propeller capable of having its pitch mechanically changed to suit conditions for the sizes now used in submarines has proved difficult to obtain in practice and of less efficiency than a compromise propeller to meet both conditions.

We are therefore driven to the design of a propeller to meet both conditions as near as possible. To do this we must decide which one is to be favored. Either the surface high or cruising speed or the submerged high or cruising speed can be favored, according to whether we are limited in obtaining power units large enough or in carrying fuel or storage battery capacity.

A safeguard is to design the propeller with an excess of area to make up for errors due to the non-fulfilment of the true pitch in both conditions and to the increase in slip due to the propeller turning faster to meet the increased resistance submerged, owing to the pitch of the compromise propeller being smaller than the pitch required for surface work. Hence the speed load curve of the electric motor should be higher in point of revolutions per minute than that of the internal-combustion engines. But this is not always possible, owing to the characteristic curve of E.H.P. required at different speeds, which is low in point of power at low speeds, compared with the engine load speed curve, which is nearly a straight line, and one has to keep the speed of the motor lower than the speed at corresponding power of the engine in the range of low speeds in order to meet the ship's E.H.P. curve.

Thus, given the engine's speed load curve, the safest course seems to be to design the motor so as to be correspondingly lower in speed for equal power in the range below half load, and higher in speed than the engine at corresponding powers in the range above half load. Then design the propeller with pitch between the pitches required for two propellers designed for each condition separately, with an excess of area and favoring the condition where there are deficiencies, and, finally, making the propellers with adjustable blades so as to be able to modify the pitch during the trial trip.

This is my idea of meeting conditions, subject to further observations during trials to come in order to discover points open to correction. Past performances only, compared with future results, can point out the most effective way for meeting and overcoming the difficulties in this line.

Safety vs. Efficiency.

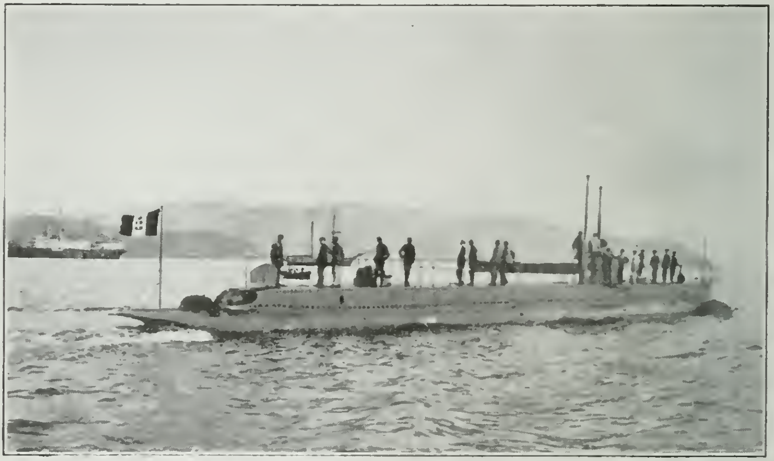
The tendency of the United States Navy Department's requirements is in the direction of multiplicity of safety devices and escape hatches, greater water-tight subdivision, etc. While this may increase efficiency by giving the crew greater confidence, additional hatches are really a source of danger, and close subdivision interferes with economical arrangement of the interior.

I believe the dare-devil type of man who would naturally choose submarine service would rather have more effective means for dealing with the enemy and take any reasonable chance on his own safety.

Of course, the Navy Department, under a government such as ours, has to keep the political and public-opinion sides of the question in mind.

Depth of Submergence.

Heretofore all United States submarines had to be subjected to a test depth of 200 feet from the axis, while all foreign submarines have been contented with 40 metres. This, in itself, is a penalty on the design of United States submarines, adding, as it does, to the weight of the hull and so increasing the size and cost of a given type of boat.



Submarine *Giacinto Pullino*, Italian Navy (Cavallini type).

At the present time the opinion seems to be growing in the United States service that a test submergence depth of 150 feet is sufficient. This means probably that, with improvements in design and growing familiarity with the handling of the vessel, the submarine operators are becoming satisfied that they will be able to avoid accidental submergence beyond this depth if they can check the sudden downward movements at all, and, if they cannot stop her before reaching 150 feet, the chances are they could not before reaching 200 feet, anyway, and therefore adopt 150 feet and save weight for other purposes.

As I understand it, the 200-foot test was originally based on consideration of the depth along the Atlantic coast, ten or fifteen miles from shore, on the theory that a vessel might go to the bottom and still be O. K. if she could stand 200 feet.

As in all other types of naval ships of war, the submarine has two general rôles, defensive and offensive.

Defensive Operations include:

Harbor defence, which, at the beginning of submarine development, was regarded as a primary duty.

Coast defence, an amplification of harbor defence, rendered possible by increase of radius of action and habitability, in virtue of which the submarine may be used to prevent landing in force or other operations along the coast anywhere within limits, equal, roughly, to nearly half their radius of action.

Offensive Operations include:

Destruction of vessels with which the enemy attempts to either hold or control the sea or to carry on military operations.

Attacking the enemy's ships and ports.

Operations in conjunction with the fleet on the high seas.

On account of the extensive coast line of the United States, submarines in number seem essential for use in *defensive operations.*

On account of the geographical location of the United States, the value of submarines for attacking enemies' ports is, for oversea enemies, smaller than is the case with European powers. In their use for the destruction of vessels with which an enemy attempts to hold the sea or for use in conjunction with the fleet, a type of boat somewhat different than that required for the strictly defensive operations would result.

From the point of view of the United States, it would seem that the desideratum is an adequate number of submarines that will actually do what is required of them theoretically; *i.e.*, some for defence near our home ports and bases, and some for operation with the fleet on broader defensive lines. To be able to obtain an adequate number it is essential that the necessary features be obtained with the least possible displacement and at the least possible cost.

For the protection of the harbors on the east and west coasts of the United States, it has been estimated by a naval authority that there should be a group of five coast defence submarines and one suitable tender stationed at each of the harbors and places which are considered worthy of protection for strategical reasons.

It has been estimated that for the proper protection of the east and west coasts of the United States there should be a total of fifty-five coast defence submarines on the east coast and a total of forty-five coast defence submarines on the west coast. It is intended that these submarines be based on mobile tenders located substantially as follows, one group of five boats operating from each base:

Submarine *Fisalia*, Italian Navy (Laurenti type).

East Coast.—Bar Harbor, Me.; Portsmouth, N. H.; Gloucester, Mass.; Provincetown, Mass.; Point Judith Breakwater; New York, N. Y.; Delaware Breakwater; Norfolk, Va.; Charleston, S. C.; Key West, Fla.; Pensacola, Fla.

West Coast.—Port Townsend, Wash., two groups; Columbia River, Ore., two groups; San Francisco, Cal., two groups; Santa Barbara, Cal., one group; San Pedro, Cal., one group; San Diego, Cal., one group.

No mention is made above of submarines for the defence of our oversea possessions, such as the Panama Canal, Atlantic and

Pacific ends, Guam, Hawaiian Islands, and the Philippines, but it is believed that at least one mobile tender in combination with a group of five coast defence submarines would be needed in each such locality, with probably several groups in the Philippines, to prevent effectually the operation of a hostile fleet in these waters.

One occasionally reads of submarines of destroyer speed, which to the layman appear entirely practicable and to the military man highly desirable, but to the submarine man it seems impossible, and certainly is to-day, meaning, as it does, about thirty knots on the surface.

The advent of the large sea-going type of submarine is a logical development in submarines, and there seems little doubt but that in the future two distinct types of submarines will be recognized to be needed; namely, a small type designed for harbor defence or coast defence, and a large type or sea-going submarine, capable of accompanying the fleet even to the waters of the enemy's country and supporting the battle fleet in a fleet action.

The essential features of the small type have already been worked out and are in successful operation and generally known, so that new development of the equipment of these boats will naturally be slow, but the conditions that the sea-going type must meet give an opportunity for increased development, particularly in the propulsion plant, both for surface work and submerged operation.

The present type of submarine, of which our navy has a considerable number, has a surface speed of from 12 to 14 knots, with a radius of action at 9 or 10 knots of from 1500 to 4500 miles. Such boats range from 250 to 550 tons displacement submerged, and have fairly small reserve buoyancy.

For a purely defensive type of submarine the 4500-mile radius is, in my opinion, entirely unnecessary, and requiring it results in a boat of considerably greater cost and size than is necessary to perform the work which it is intended to do and is capable of doing.

The sea-going, fleet speed submarine, to be used in conjunction with the fleet, is quite another matter, and the provision of long radius of action is not only justifiable, but necessary.

Considerable prominence has been given recently to the giant submarine projected by our Navy Department. What is really aimed at is a sea-keeping submarine for service with the high-sea fleet.

Public policy prevents my entering into details of the vessel desired, but there is no impropriety in my discussing briefly the general principles of such a design.

Foreign powers, by which I mean England and France, have undertaken, but not yet completed, a submarine of some 18 to 20 knots surface speed and with submerged speeds of 13 or 14 knots.

Complete details of such vessels are not available, but they naturally lead to dimensions far in excess of those of submarines now in our service.

For submarines of the coast or harbor defence type it is usual to have a hull of circular cross-section, sometimes modified toward the extremities into an ellipse, with its major axis horizontal or vertical, as required by conditions.

After exhaustive investigation I am convinced that for vessels of moderate speed requirements this form is, all things considered, the best.

When, however, one approaches the sea-keeping submarine he is confronted by another problem. Here, in order to obtain a surface speed equal to that of the fleet—of, say, 20 to 21 knots—the form given by the conventional type of circular cross-section is not suitable, and one must approach more nearly to the conventional ship-shaped form.

This results more or less logically in the double-hull type, with a circular hull within, designed to withstand pressure, and a ship-shaped lighter hull without.

The conditions of service that such a boat must fulfil demand greater conditions of habitability, free board, deck space, etc., than are necessary in the coast defence type. The percentage of reserve buoyancy must be higher than in the smaller boat to insure ample seaworthiness, and the stability should be greater.

The double hull is not always entire: *i.e.*, in some types the double hull ceases to exist at the forward and after ends, and is merged into the single ship-shaped hull.

Owing to the pressure that it must stand, the submarine's hull must always be proportionately heavier than a surface type, and when a double hull is necessary this excess of weight becomes greater still. It therefore requires but short consideration to see the difficulties that must be overcome to give a submarine destroyer speed, with its greater hull weight and its two systems of propulsion.

Operations.

All of the submarine operations so far chronicled during the present European war may be said to be in the nature of naval raids, as distinguished from strictly tactical evolutions. The surface radius of even the smaller types of submarines is quite sufficient for any of the raiding operations of which we have read.

Undoubtedly the submarine proceeds on the surface to a point where previous reports indicate that the enemies' ships are, or are apt to be, then comes to the awash conditions and waits. If his quarry is sighted, he may submerge and await him, or so direct his course as to cross that of the enemy.

The fact that he was a long way from his base was, at least in the early days of the war, an undoubted benefit to the submarine, as no one suspected him of being there, but, even if they did, his invisibility when submerged and his close approach to it even on the surface make him reasonably safe, though on a long run the crew might not be luxuriously comfortable.

It is quite possible that the submarine will continue to be most heard from in this form of operation, to which its inherent qualities are well adapted. The moral influence of this hidden danger and its constant wearing away of a near or far blockading fleet or one patrolling the seas to keep them open, as the British fleet is doing in this war, is not to be underestimated in its effect on the fleet itself or the public whom the fleet represents.

I have it on very reliable authority that the Germans in the present war, in some instances, have used a fishing boat or some other surface vessel, pretending it to be a mine-layer, as a decoy.

The question of the tactical use of the submarine in groups is, however, of importance and will become increasingly so. The maximum range for successful attack of a submarine is limited by the circle of visibility. The sea horizon, viewed from a periscope twenty feet above the surface, is just 10,000 yards. At this range the horizontal angle subtended by a 600-foot target is a little under one degree. When the periscope height is three feet above water the sea horizon is distant 4000 yards, and when one foot exposed becomes 2200 yards.

The practical difficulties of finding and then firing at specks on the horizon are so many as to compel the submarine to take advantage of her invisibility and immunity from gunfire, to push the attack to close quarters—2000 yards or less—or, if unable to do this, then to hold fire until more favorable opportunity offers.

What I shall give you now as to submarine tactics is quoted in some part from a paper prepared by one of our best submarine officers, and may be said to have the weight of experience behind it.

Before entering into a discussion of the tactics of submarines, one should first consider the various means of communication between submarines and scouts or shore stations before sighting the enemy, and between submarines themselves after sighting the enemy.

On the surface the submarine has the following means of signalling, the order of their estimated value being as given:

Radio (day or night).
Searchlight (day).
Searchlight (night).
Shape signals (day).
Flag signals (day).
Wigwag or semaphore (day).
Very's start (night).
Wigwag torch (night).

Submerged the submarine has the submarine bell signal apparatus, and, more recently, the Fessenden oscillator, which performs the same function even more satisfactorily.

The submarine bell can be used between submarines or between submarines and tenders or shore stations, at distances varying with the attending circumstances. Under the most favorable conditions (*i.e.,* all machinery stopped) signals may be exchanged at distances up to eight miles with fair success. With machinery running, and under the most unfavorable conditions (*i.e.,* boats running in opposite directions), signals may be exchanged at distances up to one-half mile.

Of the various means of signalling, none can be used in the face of the enemy without danger of betraying the presence of the submarine group.

As the submarines of the types at present in existence have a submerged speed probably inferior to the surface speed of the enemy, and as in that case the enemy can keep out of torpedo range, it is important that no signals be sent that might give the enemy warning of the presence of submarines.

It may be wise to here give definitions to the terms "light condition," "awash condition," and "submerged condition," so as to explain later references.

A submarine in the "light" condition has all of its water-ballast tanks empty and has its cruising bridge rigged.

A submarine in the "awash" condition has only those water-ballast tanks empty which are habitually kept full when running submerged. The fore-and-aft trimming tanks and two smaller tanks, called the auxiliary tank and adjusting tank, are filled with just enough ballast so that when the main ballast tanks are filled the boat will be immediately ready for running submerged without further adjustment of ballast. The quantity of water in the trimming tanks and in the auxiliary and adjusting tanks, in the "awash" condition, is so small, in comparison with the total ballast, that the submarine has practically the same stability and safety as when running "light." In the "awash" condition a small section of the bridge may be kept up for the lookout, and the conning-tower hatch may be kept open and the radio rigged.

A submarine in the "submerged" condition has the ballast tanks and other tanks so filled that there still remains a small reserve of buoyancy (0 to 800 pounds) and is all ready for submerged running.

For the purpose of tactics, submarines may be divided, according to their capabilities, into three classes, viz.: harbor defence, coast defence, and sea-keeping offensive submarines.

The tactics of a group of harbor defence submarines are simple. Their limited submerged radius and speed do not enable them to operate far from the entrance of the harbor which they are protecting. The lack of reliable under-water communication makes it impossible to change plans of action, once their group is submerged, without giving the enemy a clue as to the submarines' whereabouts. Any form of under-water signalling device in use at the present time can be accurately located in direction by the enemy. The apparatus for locating the direction of submarine signals is installed on practically every modern ship.

For this reason alone the detailed plans for a group of harbor defence submarines must be made explicit enough to cover in advance every plan of an attack by a determined enemy.

Each boat of a group would be assigned a certain area outside of the harbor as its zone of defence, these zones to be so selected that all approaches to the harbor are protected, and to be at such a distance from the point of defence that the enemy will never come within gun range.

Most of our harbors lend themselves naturally to such a method of defence by the form of the channels leading to them or by the presence of islands in the vicinity. A harbor defence group, having received warning from scouts or shore stations of the movement of the enemy off the coast, immediately proceeds to the entrance, leaving the tenders inside the harbor. Submarines anchor in the "awash" condition, radio up, in the centres of their zones, and keep a lookout for the enemy. By subdividing the total area outside of each harbor into small squares and using short code words to designate squares and directions, scouts in touch with the enemy can easily keep the waiting group of submarines informed as to the enemy's movements.

The waiting submarines, having been warned that in all probability the enemy will pass close to their harbor, are prepared and immediately get up their anchors and submerge as soon as smoke appears on the horizon.

With a moderate amount of their periscopes exposed, a submarine can easily see a large ship in clear weather for a distance of seven or eight miles. The submerged group, each boat in its zone, remains stationary until the movements of the hostile fleet are definitely ascertained. By the arrangement of the zones the enemy must pass close to one submarine; the other boats would then move over toward the enemy at such speeds and with just periscope exposure to enable them to get within torpedo range without detection. Once within torpedo range, they keep their periscopes exposed and make all speed possible to get within easy torpedo range to fire their torpedoes at that part of the enemy's formation previously assigned to them. In this last manœuvre each boat would act regardless of the other boats and must take the risk of collision. On this final charge the submarine bells may be rung continuously to assist the submarines to keep clear of each other. Having fired their torpedoes, the boats submerge totally, and reload their tubes if they have spare torpedoes. During the period of reloading they may run at such depths as would enable them to pass under the enemy's vessel, or, if the depth of the water permits, they can rest on the bottom until the reload is finished, when they should return to the surface to inflict such further attack as is possible. A submarine, having exhausted her supply of torpedoes, has still a most formidable weapon in her ram. This has been proved in several instances where accidental ramming has occurred.

The harbor defence group, having exhausted its means of offence, should return to the tender, submerged, if necessary, under cover of darkness, to replenish torpedoes and storage batteries.

For the night defence of the harbor submarines remain on the surface in their zone, being used in this manner most effectively as surface torpedo boats. The tactics on the surface as torpedo boats are similar to the tactics employed in surface torpedo craft, though as such they are somewhat less efficient, owing to their lesser speed.

The distinction between a coast defence and a harbor defence submarine lies principally in the greater submerged and surface endurance, the greater submerged and surface speed, and the better habitability conditions of the coast defence boat, which gives it a wider range of action than its smaller sister.

It will be noted that in the defence schemes for east and west coasts submarines of the coast defence types were referred to. A coast defence group will accomplish with greater effect the same duties that are now accomplished by the harbor defence group.

In considering the tactics of a group of "coast defence" boats it is assumed that information has been received from reliable sources, scouts or shore stations, that the enemy's fleet is approaching our coast with the evident intention of seizing a base or of landing a force. The group proceeds at its highest reliable surface speed, in column, in the "awash" condition, with radio up, to intercept or to come in contact with the enemy. The submarine, with its low hull, can easily distinguish the masts and other characteristics of a vessel when the submarine cannot be seen at all. On sighting the smoke or masts of the hostile fleet, and having approximately determined its course, the entire group immediately submerges, after rigging down the radio, and proceeds submerged at about one-half mile distances, in the general direction of the enemy, at such speeds and under such general instructions as may have been previously issued by the group commander. The boats of a submarine group, submerged at one-half mile distances, can easily keep clear of each other.

They should then manœuvre to keep a position on either bow of the enemy's column in order to insure their getting within torpedo range before being sighted. By "torpedo range" is meant 2000 yards. This approach must be totally submerged, with an occasional "porpoise" or periscope exposure of short duration. When within torpedo range periscopes should be exposed enough to keep an easy bearing on the enemy, and the speed increased as much as possible to arrive within easy range (between 500 and 1000 yards) before the enemy has time for a concerted manœuvre. Each submarine fires its torpedoes at the parts of the formation previously agreed upon, totally submerges, reloads as soon as possible, and returns to the attack. Using 18-inch torpedoes capable of angle fire, a four-tube boat should set one torpedo to run five degrees to port of her keel, two to run straight ahead, and one to run five degrees to starboard of her keel.

The movements of each individual boat in contact with the enemy will be dependent on the enemy's formation. A table showing the proper bearings on which to fire torpedoes with maximum changes of hits has been compiled for every possible formation, and is readily understood by submarine officers. It is not to be hoped that every shot will be a hit, nor that every ship of the enemy's force will be disabled. It is to be reasonably expected, however, with the above method of firing, enough damage will result from the discharge of twenty torpedoes to prevent the enemy from accomplishing its purpose.

With accurate knowledge of the enemy's whereabouts off the coast, two or more coast defence groups may be dispatched to the probable destination of the enemy to deliver an attack as shown above.

Submarine groups having exhausted every means of offence, including the torpedoes and ram, should withdraw submerged at low speed or lie on the bottom, if that is possible, until nightfall, and then return to the base of supplies under cover of darkness, charging their storage batteries on their way to the base.

All attacks so far have been assumed at an enemy which is moving. Should the attacking group discover the enemy at anchor, landing troops or establishing a base, it should continue as above outlined, totally submerged, with only an occasional "porpoise" of short duration, until well within torpedo range, when the periscope should be kept exposed until the torpedoes are fired at easy range at prearranged parts of the enemy's formation. No special difficulty should obtain in passing the line of the enemy's scouts or pickets with the submarines running totally submerged with occasional "porpoises."

After the reload of torpedoes the submarines must act absolutely independently, as it is probably impossible, with the present lack of under-water signal facilities, to communicate. In all cases the chief duty and aim of the group commander must be to bring all of his group *into contact with the enemy and within torpedo range at the same time*. Having done this, it is up to the individual commanding officers to produce the desired results.

A "sea-keeping offensive" submarine has been defined above as a submarine which can keep the sea, ready for duty, under all conditions of weather, for considerable periods. Such a submarine group could obtain its supplies from vessels of the fleet which it accompanies, and be as mobile as any unit of the fleet.

The tactics of such a submarine group after contact with the enemy will be the same as the tactics already described for harbor defence and coast defence submarines in contact with the enemy. The problem of manœuvring such a group into contact with the enemy, or, to state the case more accurately, the problem of manœuvring the enemy's fleet into the "submarine danger area," must be solved by the commander-in-chief.

As an illustration of the use of one or more offensive submarine groups accompanying a fleet, let it be assumed that the submarines have a surface speed capable of cruising with the fleet at any speed that may be required to keep up with the fleet. Let it also be assumed that the submerged speed and the radius of the submarines is about twelve knots for one hour, or about eight and one-half knots for four hours, or about five knots for fifteen hours—all within the range of present-day possibilities. Suppose, also, that in the cruising formation submarine groups take position on either flank of the fleet. The submarine groups are in the "awash" condition, ready for instant use. The commander-in-chief, having received information from his scouts of the presence of the enemy, or having sighted the enemy, should immediately send his submarine groups "awash" off on a bearing previously decided upon, and then endeavor to manœuvre his opponent into the area occupied by the submarines.

The submarines may remain "awash" until the enemy's smoke or masts are sighted. If our commander-in-chief possesses a superior speed, he can choose his own situation, and, having patience, can eventually bring the enemy into the submarine area. In this case submarine groups should manœuvre "awash" or "submerged," as is necessary to keep out of the enemy's sight, and endeavor to attack the enemy's formation as soon as possible without interfering with the movements of the commander-in-chief.

If our commander-in-chief has the inferior speed and inferior force, and if the enemy is determined to bring about an action, the problem of making him cross a submarine danger zone is greatly simplified. The appearance of several groups of submarines within or very close to the enemy just before a general gun action would undoubtedly cause the enemy to so alter his plans and formation that he would be at a temporary disadvantage. Even if all the torpedoes shot missed, the effect on the morale of the enemy would be sufficient to give our commander-in-chief a temporary advantage. Most of the important fleet actions have been fought in sight of land or close enough to shoals to cause the movements of the vessels in action to be somewhat restricted as to courses. In cases of this character the commander-in-chief can so station his submarine groups as to increase the chances of forcing the enemy into the submarine danger area.

If the commander-in-chief desires to withhold the submarine attack until after the gunfire, the submarine group should be kept in the background within easy radio signal distance, but in doing this the commander-in-chief will probably find that it will be more difficult for the submarine groups to make a successful dash across the space between the engaged fleets, due to the inferior speed of the submarines submerged. Ships of the enemy that are already disabled would in such cases become easy prey for the submarines. Submarine groups accompanying a fleet are decidedly offensive weapons and of the greatest value when used just preceding a general gun action.

A ruse which might assist in forcing the enemy to keep away from certain areas and thus increase the chances of making the enemy cross the submarine danger zone would consist of having the fast scouts of the fleet drop numerous poles, properly weighted, to float upright in the water, and painted to look like a submarine periscope. These same dummy periscopes floating out of a harbor with an ebb tide or dropped outside by scouts or fishermen may greatly influence the movements of an enemy sighting them. It is extremely difficult to distinguish between dummy and real periscopes, for it is easy for a submarine to lie submerged and stationary with only a small amount of periscope showing.

Something of this kind has been successfully done in fleet manœuvres several times.

The night manœuvres of a submarine craft are the same as for surface torpedo craft, and the same tactics apply. As there is no possibility of "torching," and as the hull is so low in the water, it is extremely difficult to pick them up at night, even in the full rays of the searchlight. The manœuvres off Provincetown in the summer of 1911 demonstrated that in nearly every case the submarine could come within easy torpedo range of the enemy at night without detection. In a night attack submarines should remain in the "awash" condition, so that in case of self-preservation, or to pass through a picket line, the submarine can quickly submerge.

It may very well be that while I have been talking to you the submarine has again demonstrated its effectiveness, but whether so or not, it has already done enough to make its power felt.

A weapon to which there is no defence and no reply is one not to be lightly put aside, and no navy wanting in adequate number of submarines is complete.

Street-car Tires of Rubber. ANON. (*Sci. Amer.*, cxi, No. 12, 223.)—In order to reduce the noise of street cars, and particularly the flat-wheel nuisance, it was suggested, at a recent meeting of the Tramways Association, in Newcastle, England, that street cars be provided with rubber tires. It was argued that the wear on the rails would be greatly reduced, and the life of the rubber tire would exceed that on motor trucks and 'buses, which are credited with an average life of 20,000 miles. Further, it was stated that a higher rate of speed would be possible with a flexible tire.

Ruby Color in Glass. A. E. WILLIAMS. (*Trans. Amer. Ceram. Soc.*, xvi, 284.)—Ruby glass is obtained by using as coloring agent copper, gold, selenium, or flowers of sulphur; the metals are usually found in suspension as colloids. Recipes culled from the literature on the subject are given for gold, selenium, and sulphur rubies, but the author's experiments refer to copper ruby glass. Formerly this was made by the process of flashing, which consists of placing a very thin layer of colored glass on a surface of colorless glass of normal thickness, special skill being required to blow the layer to uniform thickness in order to obtain uniform color. Now, however, ruby glass is made by pressing in moulds and reheating. The color should not be developed until the glass is reheated. Highly fluid glasses are found to "color out" quickly, viscous glasses slowly. Substitution of lead or soda for lime increases the rapidity of color development, lead more so than soda. High silica content (4 to 4.5 mols.) is necessary to give sufficient viscosity and to obtain good color; low silica tends to produce brown or black colors and opacity. With high silica in lime-potash glasses there is a tendency to streakiness, which can be reduced by small quantities of lead oxide and by remelting. Iron and manganese are detrimental to a good red color. Density of color is apparently increased by increase in temperature. The following formulæ were found most suitable for good ruby glass, 1 per cent. cream of tartar being added:

Na_2O	0.102	....	....	0.100	0.100	Equivalents.
PbO	0.627	....	....	....	....	Equivalents.
K_2O	0.202	0.536	0.536	0.536	0.536	Equivalents.
SiO_2	3.33	4.57	4.00	4.00	4.57	Equivalents.
CuO	0.067	0.023	0.023	0.023	0.023	Equivalents.
SnO_2	0.018	0.041	0.041	0.041	0.041	Equivalents.
B_2O_3	0.073	....	....	....	....	Equivalents.
CaO	....	0.44	0.44	0.34	0.34	Equivalents.

Study of the General Properties of Tool Steels. DENIS. (*Rev. de Métallurgie*, xi, 569.)—The multiplicity of tool steels all put to the same use and the differences in the results obtained on the same brands of steel in different works appear to indicate variations in the thermal treatment, owing to the neglect of carrying out systematic tests previous to the use of the steel. A certain number of brands of tool steels seem to be preferred by a large number of works, but on different grounds. To determine if this preference is based on real grounds, the author has made, in the workshops of the French Army and Navy, a systematic study of the properties of tool steels, and divides his report into three parts: (1) General considerations of the methods of testing tool steels and of the thermal treatments which may be applied to them. (2) Various tests made on the principal brands of tool steel used in industry, with the object of determining the best thermal treatment corresponding to any of their various uses. (3) Conclusions from the tests. Characteristics of the steels studied, from the point of view of their constant use.

PAINTS TO PREVENT ELECTROLYSIS IN CONCRETE STRUCTURES.*

BY

HENRY A. GARDNER,

Assistant Director, The Institute of Industrial Research, Washington, D. C.
Member of the Institute.

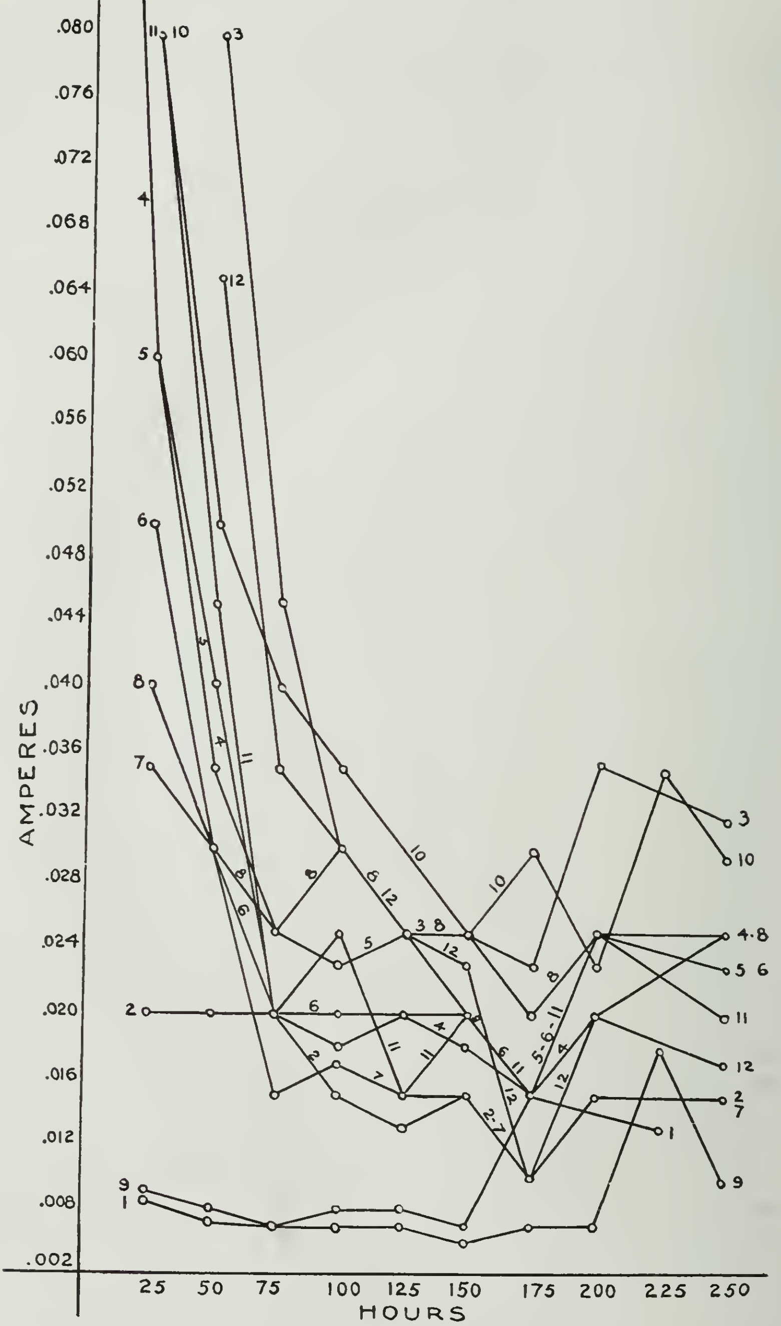
The use of protective paints upon metal that is to be embedded in concrete structures, in order to prevent any damage which might be caused by electrolysis, has been heretofore proposed. No tests have been made, however, so far as the writer is aware, which have determined what type of coating is best suited for the purpose. It would appear, from first consideration, that a paint capable of forming a film of high electrical resistance would be most efficient for the purpose. Such films, however, generally present a high gloss surface and are apt to prevent the proper bonding of the concrete with the painted metal, thus doing more harm than good. It is chiefly for this reason that engineers have not generally adopted the use of paint upon reinforcing metal. In the experiments presented herein, a method for overcoming this objectionable feature of insulating paints is described, and data are presented on the relative insulating and bonding values of several different types of paint.

Corrosion Causes.—Before describing these tests it might be well to briefly review, for the benefit of those not thoroughly familiar with the subject, some of the conditions upon which metal corrosion depends. The ordinary forms of iron corrosion have been found to be due to auto-electrolysis, the presence of segregated impurities being responsible for differences in potential at certain areas, which set up galvanic action and cause solution and the formation of rust at the positive nodes. A similar but more rapid action takes place when an electric current is passed through an iron anode immersed in an electrolyte such, for instance, as salt water. When damp cement contains an embedded iron anode the cement acts as an electrolyte, and the same rusting action takes place, regardless of the fact that concrete contains

---

* Communicated by the Author.

CHART I.


AMPERES
.080
.076
.072
.068
.064
.060
.056
.052
.048
.044
.040
.036
.032
.028
.024
.020
.016
.012
.008
.002
HOURS
25
50
75
100
125
150
175
200
225
250
11
10
3
4
12
5
6
8
7
2
9
1
5-6-11
2-7
3 8
4·8
5 6

sufficient lime to inhibit corrosion when no electrical currents are present. With the electrolytic change of metal into oxide comes an increase in volume of the products of reaction, and there is developed an enormous expansive force of mechanical pressure, which is sufficient to crack the strongest forms of concrete.

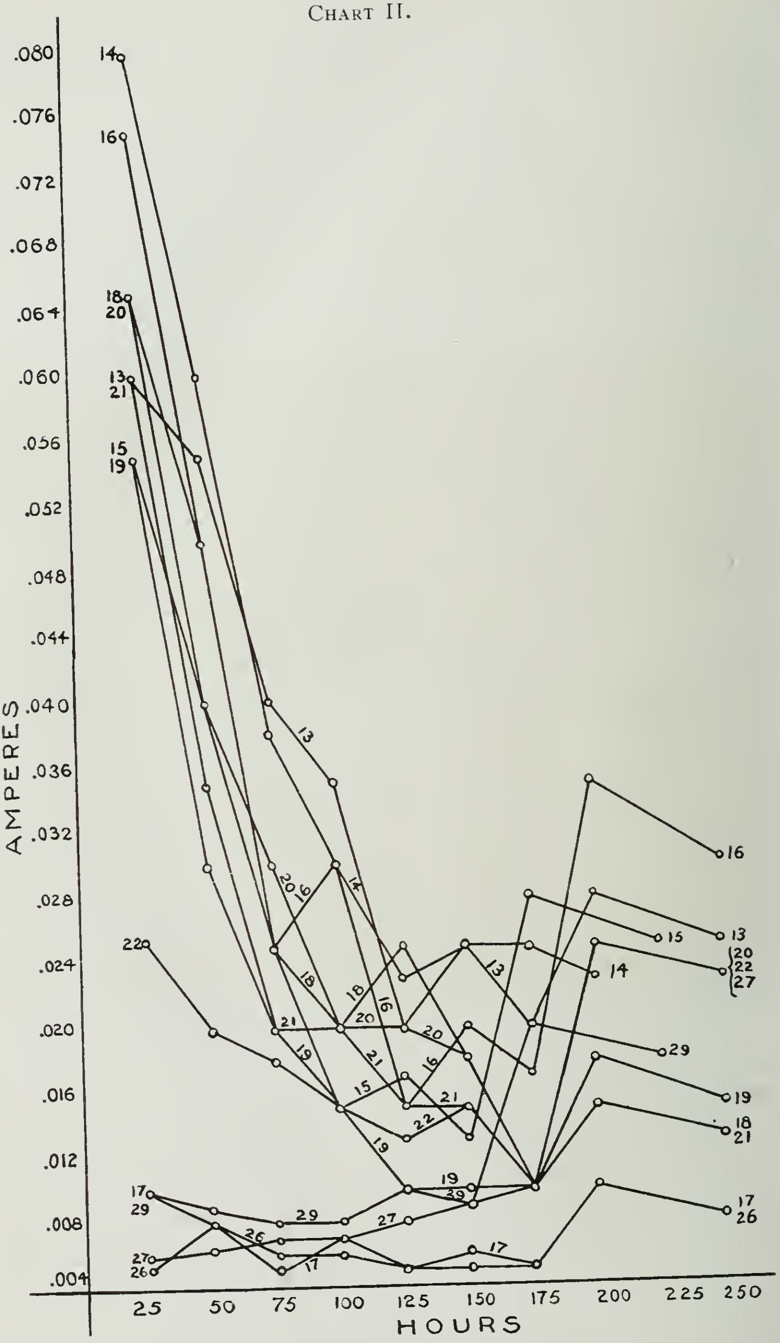
Source of Currents.—Corrosion may therefore be expected, with its attendant results, when sufficiently high voltage direct currents enter the iron of a new concrete building, either through contact with conductors of light and power circuits, contact with water or gas pipes carrying direct currents from grounded power lines, through defective insulation of electrical wiring, or from similar sources. That the damage is greatest to new structures is due to the fact that the concrete is then damp and a better electrolyte than when it becomes dry from age. That examples of reinforced concrete structures damaged from stray currents are not more common may be due to the fact that engineers are active in their endeavors to prevent high-voltage currents from running wild in many localities. This fact, however, does not justify a disregard of what might happen in the future and what may now be happening to some structures which have not been carefully guarded against stray current electrolysis. That much of this damage may be prevented by the adoption of suitable forms of foundation waterproofing, exterior insulating joints for pipe lines, isolation of lead-covered cables entering buildings, and other insulating devices, is shown by Rosa, McCollum, and Peters [1] in what is probably the most valuable contribution to the subject of reinforcement electrolysis that has ever been published. Of equal importance, however, should be the safeguarding of the metal with suitable insulating and bonding paints before it is embedded in cement. The adoption of this precaution, if followed by the use of the safety devices noted above, will guard against the causes which contribute to electrolysis and render our modern concrete structures safe from destruction by reinforcement corrosion.

Preparation of Specimens.—The writer's investigations were made upon two separate series of concrete test cylinders. The first series were made by embedding in concrete cylinders painted iron rods ½ inch in diameter and 12 inches in length. The rods,

---

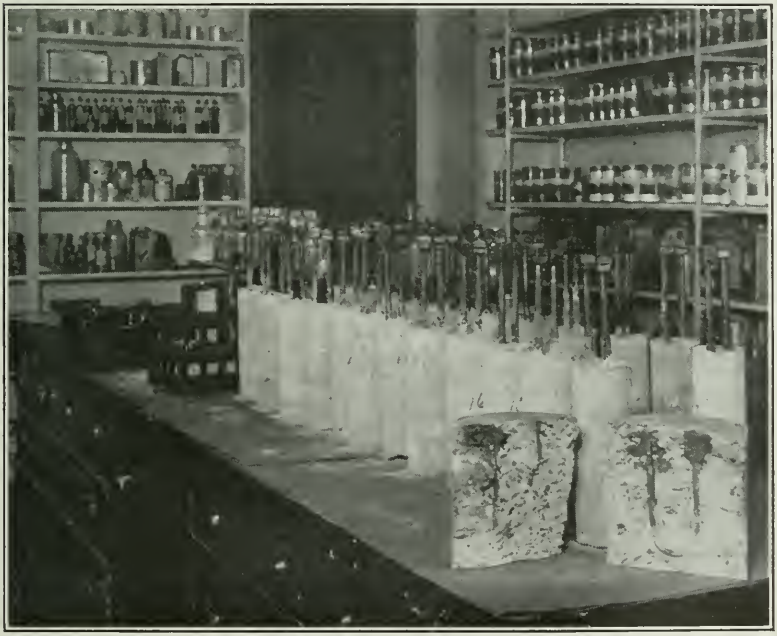
[1] "Electrolysis in Concrete," Technologic Paper No. 18, U. S. Bureau of Standards.

CHART II.


AMPERES
.080
.076
.072
.068
.064
.060
.056
.052
.048
.044
.040
.036
.032
.028
.024
.020
.016
.012
.008
.004
HOURS
25
50
75
100
125
150
175
200
225
250
14
16
18
20
13
21
15
19
22
17
29
27
26
13
14
20 16
18
18
16
20
21
20
19
21
15
16
21
22
19
19
29
29
26
27
17
17
13
16
15
13
14
20
22
27
29
19
18
21
17
26

previous to painting, were thoroughly cleaned from scale and rust. Two coats of paint were then applied, allowing a week's time for drying between coats. The painted rods were then placed in moulds in an upright position, about an inch apart and one inch from the bottom of the moulds. Cement mortar, prepared from one part of Portland cement and two parts of sand, was poured around the rods and tamped into place. After two days' time the moulds were removed and the test pieces were repaired with cement mortar wherever defects were shown.

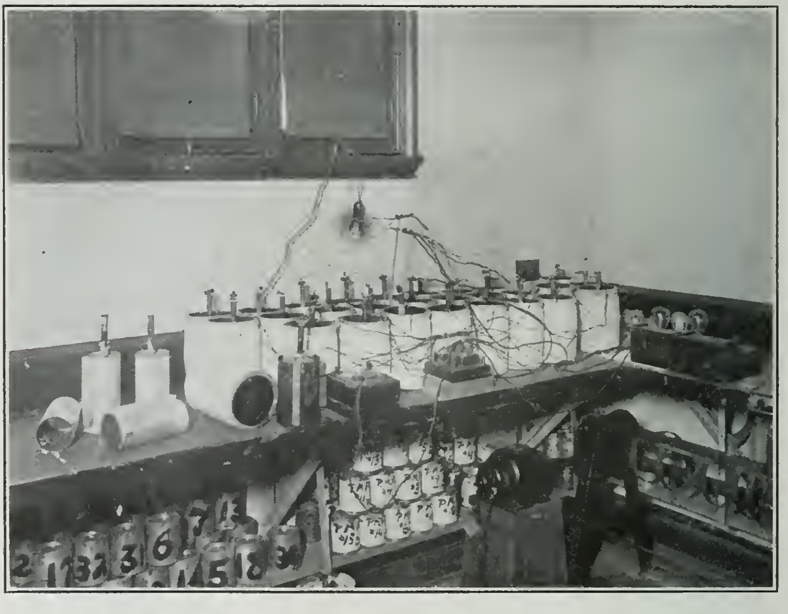
FIG. 1.



Method of Making Good Bonding Surfaces.—In making up the specimens for test it occurred to the writer that the objection to using paints which dry upon metal to a gloss surface and which prevent proper bonding of the cement might be overcome by applying to the painted surface, while it is still tacky (not dry), sharp particles of sand or similar material. Emery powder, abrasives, and fine quartz sand were among the substances tested. When allowed to drain upon a painted rod, the particles become attached to the paint and dry with it to form a rough surface resembling coarse sand-paper. After thoroughly drying, the particles are solidly embedded in the paint, which thus presents a dull rather than a gloss film. Fine, clean, white sand was found most useful.

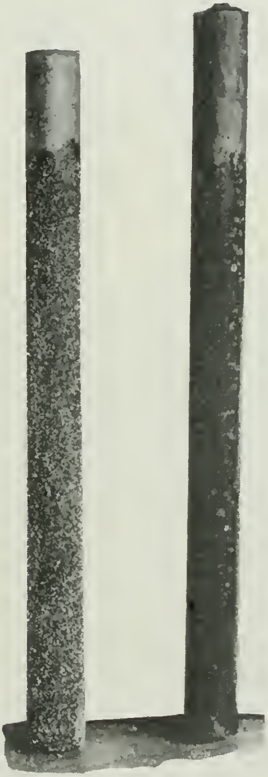
Arrangement of Tests.—After aging for a month, the pieces were connected up in parallel and in series with resistance to reduce the voltage from 110 to 30 volts direct current. Current readings were made over a period of 24 hours. The current passing was small. The test cylinders were then placed in a shallow pan containing sufficient water to immerse the lower two inches of each specimen. After a week's test, the cylinders were disconnected and removed from the pan for observation. A few of the specimens showed small cracks near the bottom, where the wet cement had conducted the current to the greatest extent. The cylinders were then placed in separate earthenware jars and again connected up. The jars contained sufficient water to immerse the specimens up to within one inch of their top surfaces. They were left in circuit for ten days and current readings were

FIG. 2.



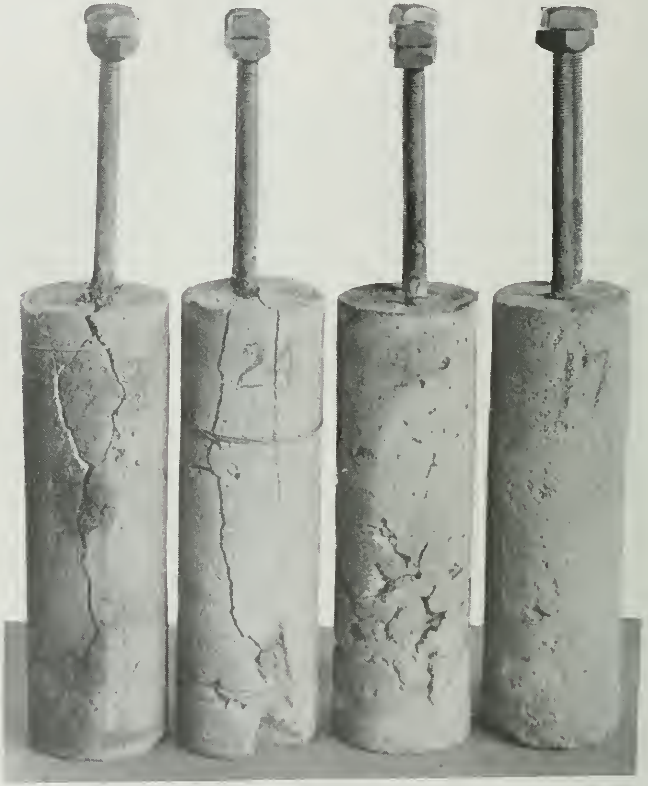
made every 24 hours. Cracking was shown by nearly every cylinder which current readings proved to be carrying any appreciable amount of current. The fracture in every case started at the anode, extending radially to the edge of the cylinders and parallel to the electrode, gradually opening up as the tests were continued. The specimens were finally disconnected and removed for examination. Those which had been cracked by the electrolytic corrosion of the metal were easily split into two sections, disclosing the contained electrodes. The others, which did not show any cracking, were parted with a chisel in order to make a comparative examination of the condition of the embedded metal.

FIG. 3.



Second Series.—In Series II the specimens were made by embedding in concrete cylinders painted anodes ¾ inch in diameter and 12 inches in length. The rods, previous to painting, were thoroughly cleaned from scale and rust. They were painted with two coats of the same paints used in Series I. The rods were placed in moulds 3½ inches by 8 inches, in an upright position, and the same kind of Portland cement mixture as used in Series I tests was placed around the rods and tamped into place. The specimens for this series were very carefully prepared and presented a much better appearance than those used in Series I. After setting for two days, the moulds were removed from the pieces, which were then aged for a month. They were then placed in water for 24 hours, and the next day were placed in individual earthenware jars containing sheet-iron cathodes coiled so as to surround, but not touch, the cylinders. The jars were filled with

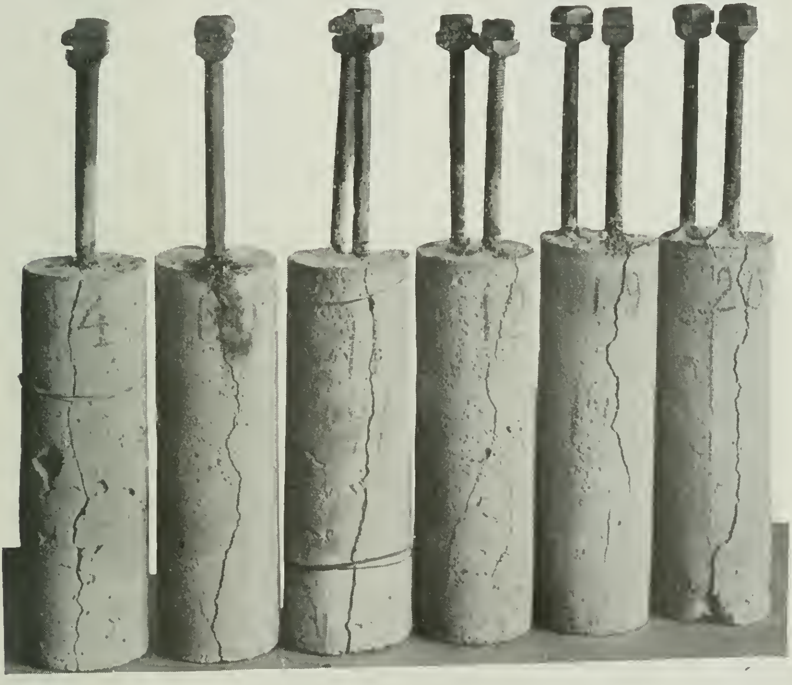
FIG. 4, Series 1.



sufficient water to cover the cylinders up to within one inch of their top surfaces. The specimens were connected up as in Series I. The tests were continued for 240 hours at 30 volts, during which time Nos. 4, 10, 11, 13, 15, 19, and 24 had developed cracks. The voltage was then increased to 55 and continued for 60 hours, at which time the tests were discontinued.

Test of Bonding Value.—In order to determine the comparative bonding strength shown by the various painted rods with the surrounding concrete, a series of test specimens was prepared, exactly duplicating those used for Series II, except that the rods were placed flush with the bottom surface of each cylinder. After aging for three weeks, the specimens were tested in a Riehle testing machine, upon an iron block drilled in the centre with a 1-inch hole. Each test specimen was placed in such a position that the lower end of the contained iron anode would be in alignment with the hole below. Pressure was applied until the painted iron rod

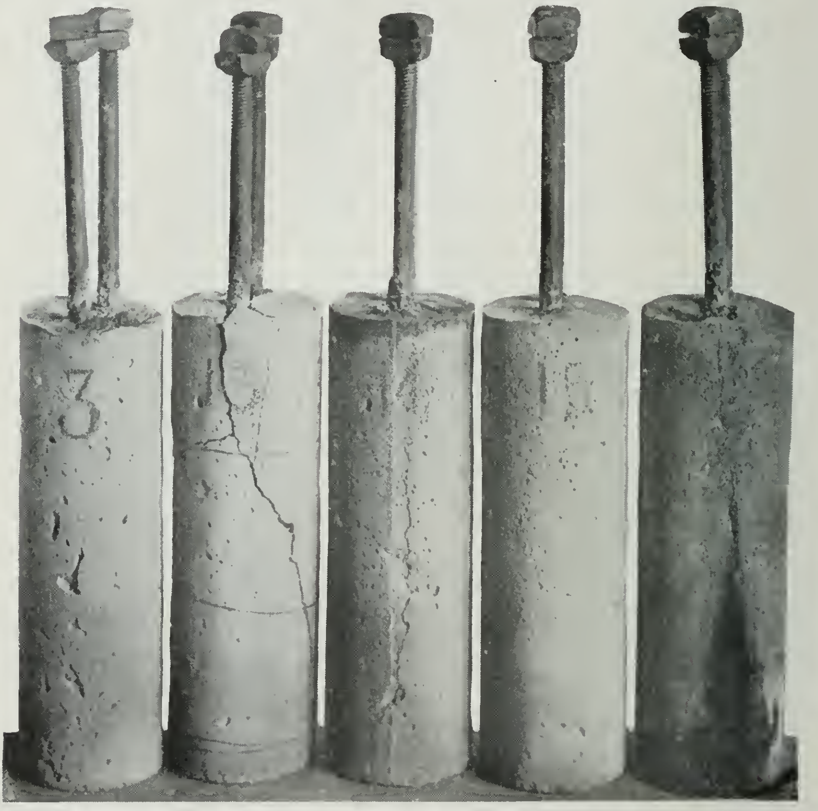
FIG. 5, Series 1.



was pushed away from the surrounding cement and the bond destroyed.

Observations on Results.—In the test specimens where cracking had occurred the anodes showed considerable rust, the paint coatings originally applied having been destroyed. On the cathodes in Series I the paint coatings were still intact, although some had apparently been affected by the moisture and the hydrated lime in the wet concrete, chalky surfaces being shown. Wherever there were small voids in the concrete, at or around the painted anodes, corrosion was most severe, and at such places pitting was shown. The protective coatings upon the anode and cathode bars embedded in the concrete cylinders which did not

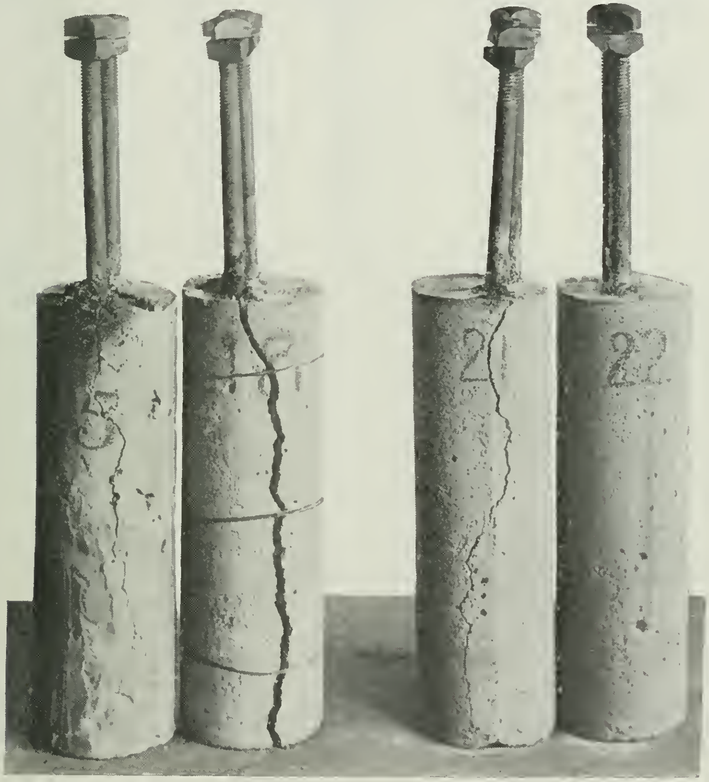
FIG. 6, Series I.



crack and which carried but little current were later found to be in a very good state of preservation.

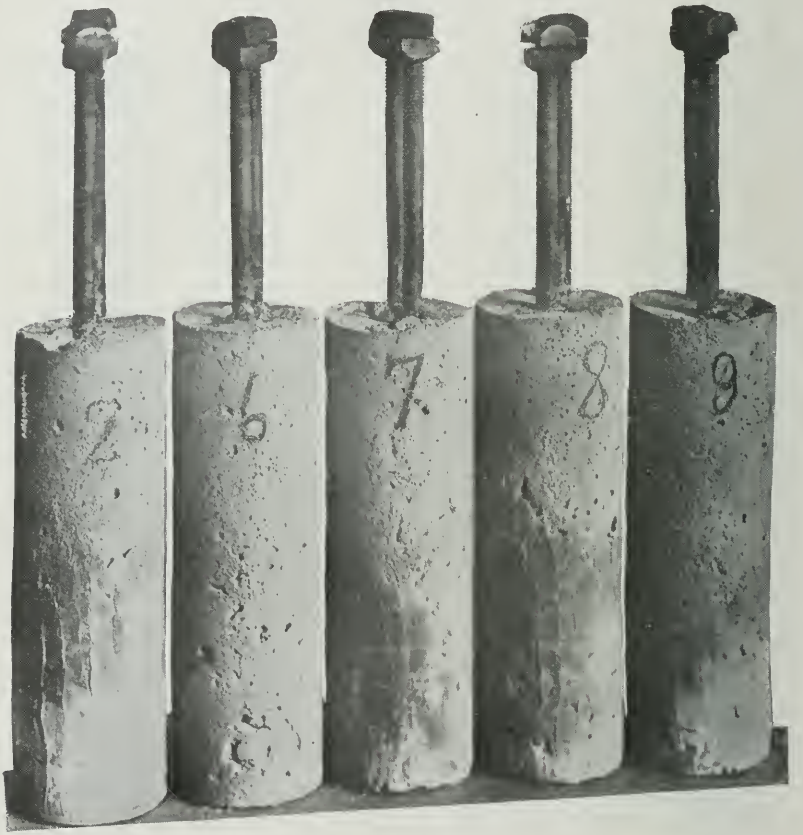
Incidental Reactions.—The breaking down of a film upon the embedded iron rods was always recorded by a sharp rise in the amperage, due to the decreased resistance offered to the flow of the current between the electrodes. It was also recorded by a fizzing sound, due to the increased evolution of hydrogen gas developed by the electrolysis of the water in the damp concrete. This gas, issuing from around the iron electrode at the top of the test pieces, generally carried some water with it, and small bubbles were formed, which burst with an audible explosion when a lighted match was placed in contact with them. The hydrogen gas

FIG. 7. Series I.



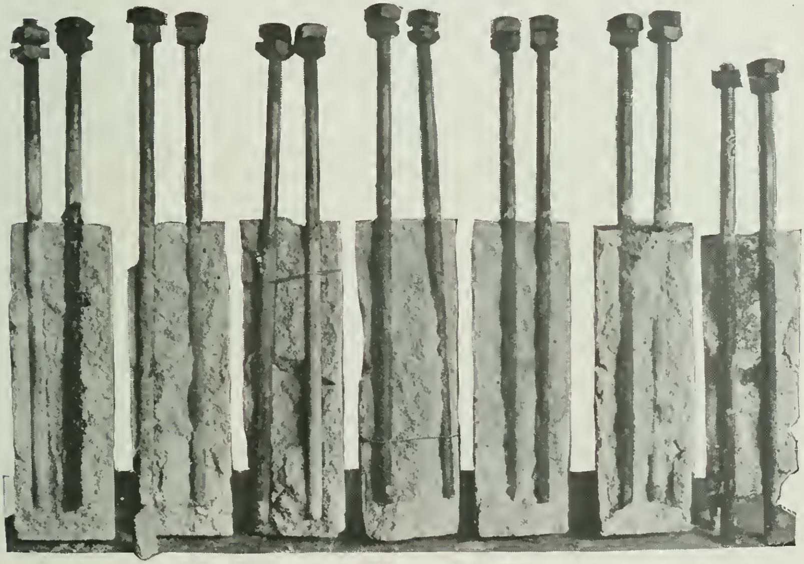
seemed to have a reducing or softening action upon some of the oxidized coatings, and carried to the surfaces of the cylinders considerable quantities of soft oily products, which deposited around the anode and later hardened in contact with the air. Iron oxide was also carried to the top surfaces of some of the specimens by the action of the gas and water, and was there deposited as a dark brown stain.

FIG. 8, Series 1.



Electrolytic Hydrogenation of Oil Films.—That the nature of the paint films has considerable bearing upon the action of the hydrogen gas which was found to be developed during the tests there can be no doubt. In an investigation to determine the cause of the rapid corrosion exhibited by some grades of lacquered tin food containers, W. H. Walker[2] and Slade[3] have found linseed oil films to act as depolarizers of hydrogen, and Walker points out that such films, if in a semi-oxidized condition, may absorb hydrogen quite as rapidly as oxygen. This may account for the appearance of the oily substances brought to the top of some of the cylinders. Electrolytic hydrogenation may have been effected by the action of the nascent hydrogen in the presence of iron oxide or other pigments which could act as catalyzers. The action was sufficient to produce a product which, although fluid when formed, on account of the warmth of the cylinders at the anode where heat was developed by the electrolysis, later became solid when deposited upon the surface of the cylinders. It was in specimens showing such surface deposits that the bond between the cement and steel was the weakest.

FIG. 9, Series 1.



Value of Well Dried and Saturated Films.—Walker has also referred to the fact that paint films that have been baked, on account of their fully saturated condition, do not act as depolarizers. It would obviously be impractical to bake paint coatings upon most forms of reinforcing metal, but quite thoroughly oxidized coatings, which would probably have but slight depolarizing action, would result by allowing a period of 60 days for the drying of oil paints after application to the metal and previous to immersion in the cement. It is, moreover, possible to apply coatings which do not depend entirely upon oxygen absorption for their hardening and which contain ingredients of a fairly saturated

---

[2] "Paint and Varnish Coatings as Accelerators in the Corrosion of Metals," W. H. Walker and W. K. Lewis, *J. Ind. and Engrg. Chem.*, 1909, vol. i, p. 754.

[3] "A New Method for Testing Paint Films and Preservative Coatings for Iron and Steel," W. C. Slade, *J. Ind. and Engrg. Chem.*, 1912, vol. iv, p. 189.

FIG. 10, Series 2.

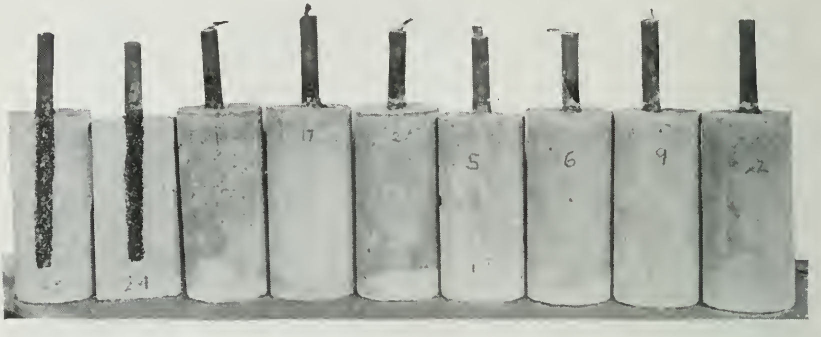
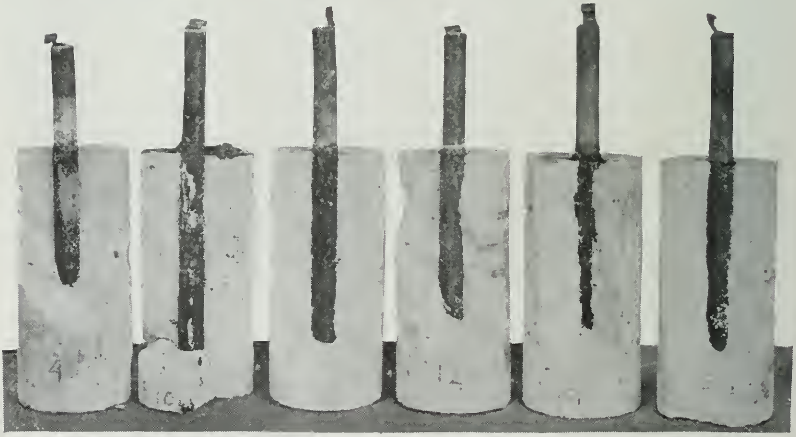


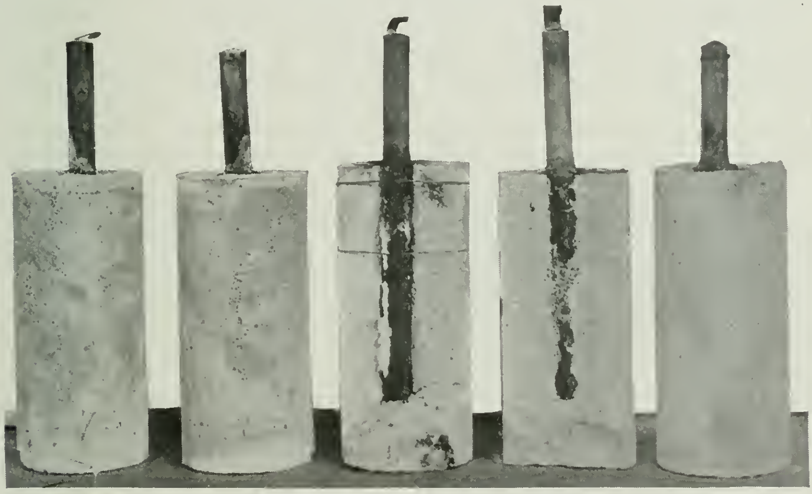
FIG. 11, Series 2.



nature. Among these could be mentioned such coatings as are composed of resins dissolved in volatile solvents, as well as some special types of oil coatings which gave good results in Series I and II.

Relation between Film Porosity and Electrolysis.—The small current flow shown by certain of the specimens in the test may in part be attributed to their impervious character. Paints which form porous films allow the passage of water which may contain various electrolytes. Such films offer but small resistance to the passage of electrical currents. Paints which form highly impermeable films keep water away from the underlying iron and offer great resistance to the passage of electrical currents. Investigations which have determined the actual degree of porosity shown by various types of paint films have previously been made by A. M. Muckenfuss [4] and by the writer.[5] These tests have already afforded useful information to the designer of paints, and might

FIG. 12, Series 2.



---

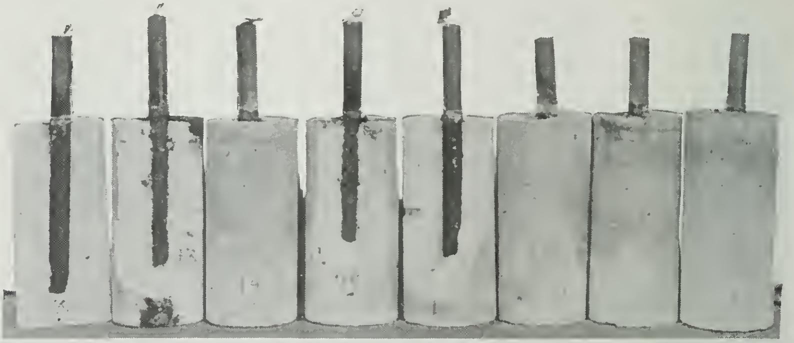
[4] "Report on a Permeability Test for Paints and Varnishes," A. M. Muckenfuss, *Proc. Amer. Soc. for Test. Mater.*, vol. xiv, Part 2, p. 361 (1914).

[5] "Excluding and Water-resisting Properties of Paint Films for the Protection of Iron and Steel," H. A. Gardner, Bull. 18, Scientific Section, Paint Mfrs.' Assn. of U. S., p. 17.

be studied with profit in the production of paints for the prevention of electrolytic corrosion.

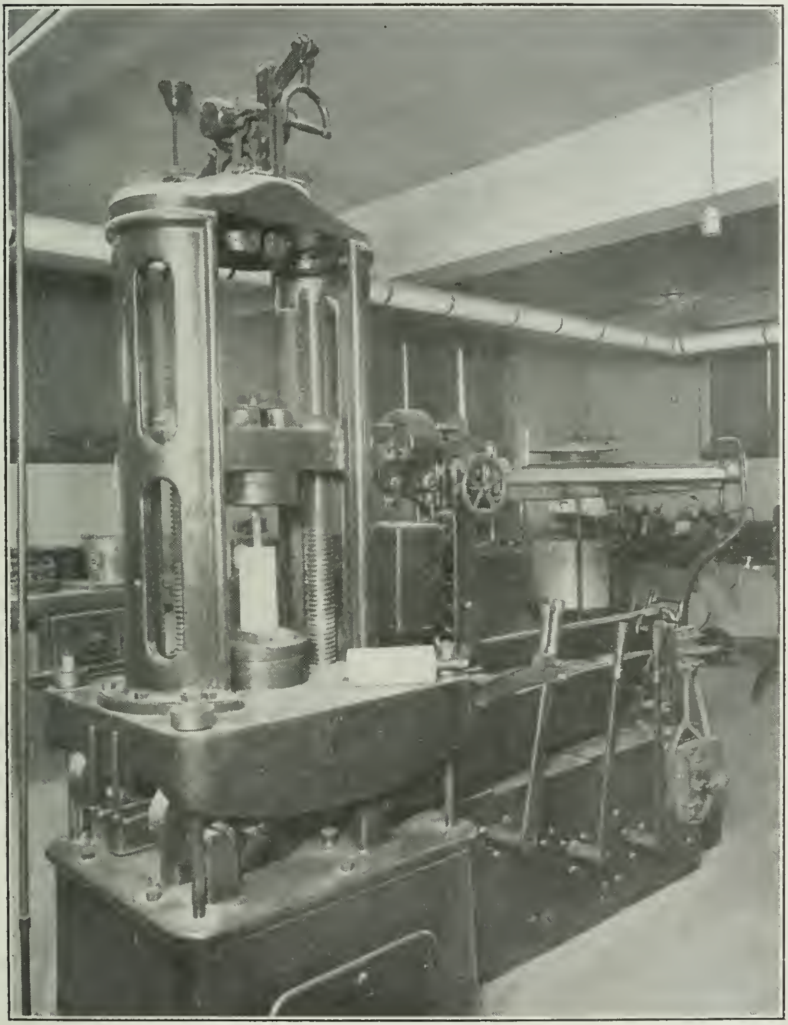
Discussion of Bonding Tests.—Some paints gave good bonding tests, but failed to act as insulators. Among these may be mentioned Nos. 12, 19, and 20 (water paints) and Nos. 18 and 21 (lacquers). The latter two, composed of collodion and gutta-percha respectively, dried to a flat surface, which accounts for the good bond tests shown. Among the oil paints, No. 16, which also had the property of drying to a flat surface, gave a much better bond than paints of a similar composition which dried to a gloss surface. The good bonding tests shown by several of the water paints is readily explainable, the wet concrete exerting a solvent action upon such paints, which gave opportunity for direct contact with the steel. Some paints which gave excellent results in the insulating tests gave conversely poor results in the bonding tests. Among these may be mentioned Nos. 7 and 8, composed of sandarac and shellac respectively. Most of the oil-pigment paints made with raw linseed oil gave poor or only fair results. It is probable that the raw oil fails to dry hard, and, although apparently well dried, remains in a semi-oxidized condition. The oil films would in such cases be rather porous and therefore inefficient as insulators. Such films would be readily acted upon by the hydrogen evolved by electrolysis. Much better results were obtained with boiled linseed oil, a product that dries to a harder, less porous, and more fully saturated film. The value of the "sanded surface" method is shown by comparing test No. 27

FIG. 13, Series 2.



with test No. 15, the paints used being of the same composition. The sanded surface of No. 27 gave much better insulating values and its bonding strength was double that of the unsanded specimen. Another instance of the value of the "sanded surface" method is shown by a comparison of specimens Nos. 28 and 14.

FIG. 14, Series 3.



Use of Pigments.—It is quite likely that the nature of the pigment used in a paint designed to prevent electrolysis of embedded metal will have some bearing upon the results obtained from its use. The addition of a pigment to an oil usually increases the resistance to moisture and makes a more impermeable film. Theoretically, pigments which are of a non-conducting nature should be preferable. The inert pigments are examples of this type (asbestine, china clay, silica, etc.). There should, however, be present in a paint a sufficient quantity of rust-inhibitive pigment (basic pigments or pigments of the chromate type) to produce a passive condition of the steel, similar to the condition that is produced by the basic lime compounds in cement.

Prominent among the protective compounds that gave the best results are Nos. 2 and 9, composed of processed and heat-treated tung oil (Chinese wood oil). These compounds dried to a hard, non-porous film of a saturated nature. Had they been sanded, they undoubtedly would have given still better results. Distinction should also be accorded to Nos. 17, 27, and 28, although the good results obtained with the last two should be largely credited to the sanding of the surfaces during drying.

Arrangement of Results.—The protective compounds used in the tests have been divided into groups or types, and the composition of each is presented below. The formula numbers given correspond with the numbers of the test pieces containing rods to which such paints were applied. The same paints were used for the first and second series of corrosion tests, as well as for the bond tests. The tables also show the results obtained in each series of tests, and give the comparative bonding strength of each specimen. Charts I and II show the results of Series II and amperage hours. Figures 1 to 14 present the appearance of the various specimens tested.

Conclusions.—The corrosion of metal embedded in concrete structures, by stray currents of high voltage, is often productive of serious effects. The use of properly-made paints upon such metal constitutes a safeguard that should not be neglected by the engineer. Such paints may be prepared from the following substances.

The vehicle should contain:

Boiled or bodied oils or products which dry to a fairly saturated film.

Oils which dry by semi-polymerization rather than oxidation.

Oils which dry to a flat rather than a highly gloss surface.

The solid portion should contain a percentage of:

Pigments which are coarse and which therefore tend to form films having a rough surface.

Pigments which are inert and which do not act as conductors of electricity.

Pigments which are either basic or of the chromate type.

The painted metal should be "sanded" if possible.

The writer wishes to acknowledge the very valuable assistance throughout these tests of Mr. Leland P. Hart.

UNPAINTED BLANK SPECIMENS

Test specimen	Composition of paint	Results in Series I, 500-hour test	Results in Series II, 300-hour test	Series III, comparative bonding strength, pounds
23	Electrodes not painted.	Cracked at end of 240 hrs. Passed large amount of current throughout test. Anodes badly corroded and pitted.	Cracked at end of 96 hours. Passed large amount of current throughout test. Anodes badly corroded and pitted.	2010
24	Electrodes not painted.	Cracked at end of 50 hours. Same condition as No. 23.	Cracked at end of 96 hours. Same condition as No. 23.	2750

BITUMINOUS PAINT

Test specimen	Composition of paint	Results in Series I, 500-hour test	Results in Series II, 300-hour test	Series III, comparative bonding strength, pounds
1	Mixture of boiled, water-free coal-tar, lime, Portland cement, and rosin, thinned with benzol.	No cracking shown. Passed only small amount of current. Some excretion of tar paint at anode.	No cracking shown. Passed only small amount of current.	1530
17	Mixture of blown residual petroleum oil fluxed with gilsonite, dissolved in benzol and turpentine.	No cracking shown. Passed only small amount of current.	No cracking shown. Passed only small amount of current.	2810

OIL PAINTS

Test specimen	Composition of paint	Results in Series I	Results in Series II	Series III, comparative bonding strength, pounds
3	Red lead in oil. 30 pounds pigment to one gallon of raw linseed oil.	Did not crack, but large quantity of iron hydrate deposited at top surface of specimen, staining the concrete, showing weakened bond and corrosion.	Cracked at end of 192 hours. Considerable iron hydrate stain shown at surface of specimen throughout test. Iron quite badly corroded.	1370
13	Chrome green, 20 per cent. on 80 per cent. barytes base, ground in raw linseed oil (medium).	Cracked at end of 240 hours. Iron hydrate stain shown around anode at top surface of specimen early in test. Iron quite badly corroded.	Cracked at end of 192 hours. Same conditions observed as in Series I.	790
14	Blue lead in oil. 14 pounds pigment to one gallon raw linseed oil.	No cracking shown. Resistance to current was not marked. Slight corrosion observed. Deposit of iron hydrate at surface of cylinder.	No cracking shown. Same conditions observed as in Series I.	1250
15	Chromated iron oxide in oil. 12 pounds pigment to one gallon raw linseed oil.	No cracking shown. Only slight corrosion observed.	Cracked at end of 144 hours. Deposit of iron oxide at top of cylinder.	930
16	Blue lead ground in heavy-bodied linseed oil reduced with an equal quantity of turpentine to cause paint to dry to a flat surface. Formed a thin film.	Small crack developed at end of 240 hours. No surface deposit shown, indicating good bond. Anode showed considerable corrosion.	Small crack developed at end of 216 hours. Same condition as in Series I.	1400
27	Chromated iron oxide in treated tung oil. 12 pounds pigment to 1 gallon raw linseed oil. "Sanded surface."	Not in Series I.	No cracking shown. Passed only small amount of current. No deposit on surface. Excellent condition.	2000

OIL PAINTS—*Continued*

Test specimen	Composition of paint	Results in Series I	Results in Series II	Series III, comparative bonding strength, pounds
28	Mixture of equal parts of No. 14 and No. 16. "Sanded surface."	Not in Series I.	No cracking shown.	1880
29	Asbestine pigment ground in No. 9 oil. "Sanded surface."	Not in Series I.	No cracking shown. Passed only very small amount of current. Passed slightly more current than No. 9. In excellent condition throughout test.	Not in Series III.

AQUEOUS PAINTS

Test specimen	Composition of paint	Results in Series I	Results in Series II	Series III, comparative bonding strength, pounds
4	Silicate of soda (40° Be.).	Cracked at end of 240 hours. Very little resistance to current.	Cracked at end of 168 hours. Very little resistance to current. Examination of iron showed some clear areas and some pitted.	700
10	Liquid glue.	Cracked at end of 240 hrs. Passed large amount of current throughout test. Considerable iron hydrate at top of specimen and permeated throughout. Concrete around anode.	Cracked at end of 96 hours. Passed large amount of current. Dense deposit of iron hydrate at top of test piece. Bad corrosion of metal shown.	100
11	Silicate of soda, 20° Be., and graphite ground together, equal parts by weight.	Cracked at end of 144 hrs. Passed considerable current. Corrosion marked.	Cracked at end of 96 hours. Passed large amount of current. Corrosion marked.	Specimen faulty.

AQUEOUS PAINTS—*Continued*

Test specimen	Composition of paint	Results in Series I	Results in Series II	Series III, comparative bonding strength, pounds
12	Silicate of soda, 20° Be., and iron oxide pigment ground together, equal parts by weight.	Cracked at end of 240 hrs. Passed considerable current.	Cracked at end of 192 hrs. Passed considerable current.	1870
19	5 per cent. aqueous solution of sodium resinate.	Cracked at end of 240 hrs. Passed more current than one blank specimen.	Cracked at end of 144 hrs. Passed considerable current.	1890
20	5 per cent. aqueous solution of sodium resinate ground with an equal weight of iron oxide.	Cracked at end of 240 hrs. Passed large amount of current.	Cracked at end of 196 hrs. Passed large amount of current.	2580

LACQUERS

Test specimen	Composition of paint	Results in Series I	Results in Series II	Series III, comparative bonding strength, pounds
7	Gum sandarac in alalcohol, 32 ounces solution.	No cracking shown. Only small amount of current passed. No stain at surface.	Only small amount of current passed. No stain at surface.	990
8	Gum shellac in alcohol, 32 ounces solution.	No cracking shown. Passed more current than No. 7. No stain.	Passed more current than No. 7. Slight stain at surface.	490
18	Soluble nitrated cotton dissolved in amyl and ethyl acetate, 8 ounces solution.	Cracked at end of 240 hours. Large amount of current passed. Some stain at surface.	Cracked at end of 192 hrs. Large amount of current passed. Iron hydrate stain at surface.	2480
21	Gutta - percha dissolved in benzol, 3 ounces solution.	Cracked at end of 240 hrs. Passed considerable current. Stain at surface.	Cracked at end of 96 hours. Passed considerable current. Considerable stain at surface.	2600

LACQUERS—*Continued*

Test specimen	Composition of paint	Results in Series I	Results in Series II	Series III, comparative bonding strength, pounds
26	Condensation product of phenol and formaldehyde dissolved in alcohol.	Not in Series I.	No cracking shown. Passed only small amount of current. Some iron stain at surface and a small deposit of dark cherry stain, due to product of reaction between the phenolic bodies and the lime in the cement.	1380

OILS AND VARNISHES

Test specimen	Composition of paint	Results in Series I	Results in Series II	Series III, comparative bonding strength, pounds
2	Special heat-treated tung oil compound thinned with turpentine.	No cracking shown. Concrete test specimen was of faulty construction, a portion of the cathode being exposed. Nevertheless the specimen passed but very small amount of current. Film was tough and elastic.	No cracking shown. Only moderate amount of current passed. No stain.	2665
5	Double-boiled linseed oil (lead and manganese drier).	Cracked at end of 140 hours. Passed considerable current throughout test. Heavy deposit of iron stain at surface.	Only a very fine crack developed at end of test. Passed considerable current throughout test. No stain.	1680

OILS AND VARNISHES—*Continued*

Test specimen	Composition of paint	Results in Series I	Results in Series II	Series III, comparative bonding strength, pounds
6	Kauri gum-linseed oil varnish.	Only slight crack shown. Small amount of current passed. No stain.	No cracking shown. No stain.	1790
9	Processed tung oil compound.	No cracking shown. Passed only a very small amount of current. Gave excellent insulation value. No stain.	No cracking shown. Passed only a very small amount of current. Had a high electrical resistance. No stain.	1990
22	Mixture of equal parts of No. 9 and No. 21.	No cracking shown. Passed less current than No. 21, but more than No. 9. No stain.	No cracking. Passed less current than No. 21, but more than No. 9. No stain.	Specimen faulty.

Two New Modifications of Phosphorus. P. W. BRIDGMAN. (*Amer. Chem. Soc. Journ.*, xxxvi, 1344.)—Under the influence of high pressure, ordinary white phosphorus is transformed into a new modification. The transition temperature is a linear function of the pressure and varies from about – 80° C. at the atmospheric pressure to + 64.4° C. at 12,000 kg. per square centimetre. This modification was obtained in microscopic crystals, probably in the hexagonal system. A black modification has also been obtained by subjecting the ordinary white form to a temperature of 200° C. and a pressure of 12,000 kg. per square centimetre. This variety, the formation of which is irreversible, has the high density 2.691 at the ordinary temperature, and possesses moderately high electrical and thermal conductivity. Its specific heat between 30° C. and 100° C. is 0.170, which is decidedly lower than the corresponding value for red phosphorus, the latter being apparently less stable than the black form.

Protecting Garment for Aviators. ANON. (*Sci. Amer.*, cxi, No. 12, 223.)—Richard Kockrow, of Nieder, Lausitz, Germany, has secured a patent, No. 1,104,808, for an aviator's protecting garment, formed of layers of felt and aluminum, spring-spaced apart to protect the wearer from the shock in case of a fall.

METHODS, DATA, AND NEW APPARATUS FOR MEASURING ELECTRICAL CONDUCTIVITY ABOVE 1500° C. OF VAPORS AT NORMAL PRESSURE.*

BY

EDWIN F. NORTHRUP, Ph.D.,

Palmer Physical Laboratory, Princeton University.
Member of the Institute.

It is certain that when the temperature exceeds 1200° C. many substances, ordinarily called insulators, conduct electricity fairly well. It is probable that near and above this temperature every known material, whether in the solid, liquid, or vapor condition, is a fair conductor of electricity. By this statement I mean that a pressure of less than 100 volts will send enough current through a section of a square centimetre and a few millimetres of length of the material to be readily measured with an instrument reading in milliampères. With further elevation of temperature, to the neighborhood of 1600° C., the so-called refractories, ordinary gases, and some, at least, of the metallic vapors, acquire a conductivity which is readily measured with the ordinary deflection instruments: a voltmeter and a milliampèremeter. The conduction here referred to is not arc conduction, and the current which flows steadily increases with application of voltage from zero voltage to a voltage less than 100 volts, ordinarily. The ratio of the voltage to the current is not, however, constant and obeys no simple law.

While the general fact has long been known that very hot gases and vapors are more or less conducting at high temperatures and at atmospheric pressure, so far as my reading informs me, the facts and laws of the conduction have received little study and few quantitative measurements have been made. The subject has appeared to me to have both practical and theoretical value, and I have begun an extended investigation along this line, and what follows is a brief report of the beginnings made.

---

* Read by title at the meeting of Section D, A. A. A. S., December 31, 1914, and communicated by the Author.

Gas and vapor conduction investigations have been heretofore confined chiefly to experiments carried on at ordinary temperature and low pressure. The gases or vapors investigated under these conditions would, if liquefied, be classed as insulators. If, however, we investigate the conductivity of a metallic vapor, we study the conductance of a substance which if liquefied becomes an excellent metallic conductor. The greater number of the metals, however, do not exist as vapors except at very elevated temperatures, and hence, to investigate the nature of the conduction of vapors which if liquefied become good conductors, we must work at very high temperature. If we can combine high pressure with high temperature we shall have at our disposal a searching experimental method of ascertaining the true nature of metallic conduction.

The investigation requires:

(*a*) Suitable apparatus for controlling and bringing the temperature of a confined space from 1400° C. to 1800° C. (2552° F. to 3272° F.);

(*b*) A rapid and certain means of measuring the high temperature employed;

(*c*) Suitable containers for the metallic vapors under study;

(*d*) Suitable apparatus for maintaining the hot vapors under high pressure.

Some progress has been made in all these developments except the last, which has not yet been attempted.

Preliminary experiments showed that the character of the conduction depends:

1. Upon the form of the container;
2. Probably upon the material of the container;
3. Upon the applied voltage;
4. Upon the direction of the applied voltage;
5. Upon the temperature;
6. Upon the frequency when an alternating voltage is employed;
7. Upon the nature of the gas or vapor.

It soon became apparent that, in order to discover, measure, and interpret the phenomena, the measurements should be made with unidirectional e.m.f. which could be commutated, and then be repeated with an alternating e.m.f. of different known frequencies.

When a unidirectional e.m.f. is employed the measuring apparatus may consist of a d.-c. voltmeter, reading to 150 volts, and d.-c. milliampèremeters with scales arranged to read from 10 to 1500 milliampères at the top of the scale. When an alternating e.m.f. is employed I have used an electrodynamometer of the Rowland type in conjunction with a Wheatstone bridge. An a.-c. milliameter and a.-c. voltmeter could and should be used to check and help to interpret the results gotten with a Wheatstone bridge.

The piece of apparatus which required the greatest amount of thought and experimentation for satisfactory construction was the electric furnace. The experience which had been acquired in developing a large-model, high-temperature graphite furnace, which gives readily 1600° C. (2912° F.), enabled the furnace problem to be solved in an entirely satisfactory way. It was found, after making several life tests, that a graphite heater-unit, while entirely satisfactory for a large furnace, is less so for a small furnace, and an interchangeable heater-unit which employs a very high melting-point metal as a resister material was devised, which fits into the same space in exactly the same kind of a furnace case as had been previously constructed for a small-model graphite furnace. Another reason for employing a metal for a resister element lies in the fact that, when the furnace is heated slowly, the furnace resistance, which may be obtained by reading volts and ampères or volts and watts, bears a definite relation to the temperature of the furnace. The curve relating temperature and resistance is obtained by heating the furnace very slowly and noting its resistance at the moment at which small wires of different metals, whose melting-points are known, melt. For this purpose I use the wires, aluminum, copper, and nickel. When more precision is required in the measurement of temperature, a thermocouple or tin pyrometer, or an optical pyrometer may be used.

Fig. 1 is a curve relating resistance and temperature of one of the heater-units belonging to the furnace used in my measurements.

This type of furnace has a chamber of cylindrical form 2.2 Cm. in diameter and a heating length of about 13 Cm. The metal resister material is protected from oxidation by the $CO + N$ gases which the furnace automatically develops as soon as a red heat is reached. The furnace may be safely heated to a temperature which will melt platinum. In a test made on one of the units the furnace was heated and cooled ten times. In two of the heatings the temperature was raised to over the melting-point of platinum. After this the current was kept on continually until the unit gave out. The unit lasted a total of 137½ hours, the temperature seldom going below 1400° C. and most of the time being above the melting-point of nickel. Some minor changes have been made, suggested by the results of this test, which will still further increase the life of the heater-units. The watt input required to give an equilibrium temperature above the melting-point of nickel was about 1030 watts. When it is desired to heat the furnace rapidly from room temperature to 1500° C. an input of about 1600 watts is used. In one test an input of 1660 watts brought the furnace to an equilibrium temperature of 1645° C. in about 2½ hours. When at this temperature the furnace called for 28.6 volts and 58 ampères.

FIG. 1.

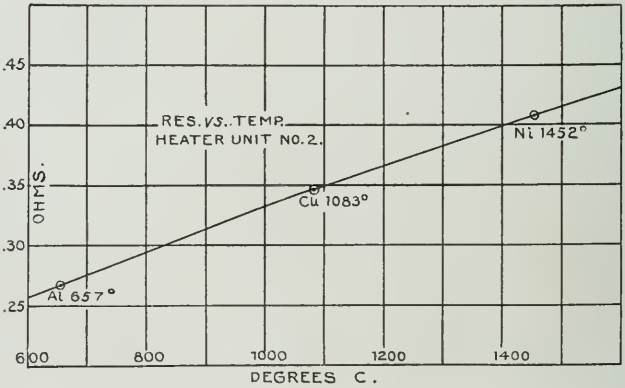
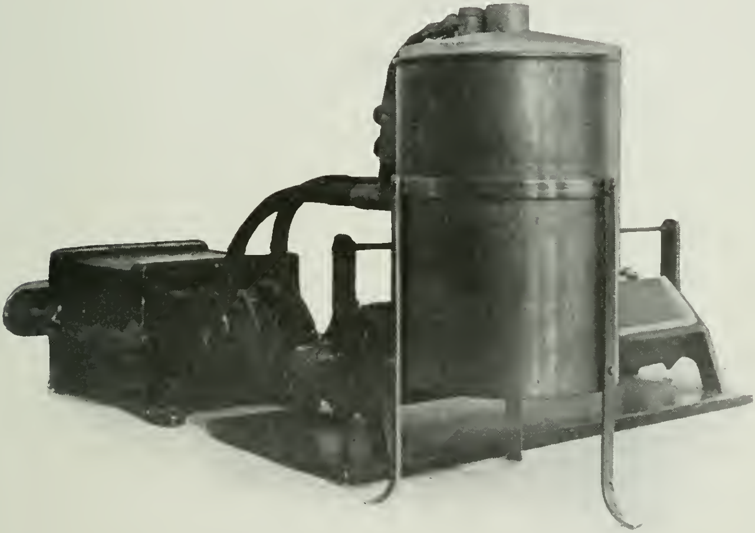


Fig. 2 is a reproduction of a photograph of the furnace, transformer, and carbon rheostat, which together make up the furnace outfit. The replaceable unit is shown in Fig. 3.

An exhausted unit is very readily replaced by a new one, when the full life of the furnace becomes restored.

To hold the heated vapor to be measured a container of Acheson graphite was devised. This is illustrated in Fig. 4. It consists of a crucible of cylindrical form which fits the furnace chamber. A hollow cylinder of graphite 8 mm. in external diameter is located on the axis of this crucible. It is held in position and insulated from the crucible by a piece of baked lavite, which also forms a cover for the furnace chamber. The resistance measured is that of the hot gas or vapor in the space between the outer surface of the inner cylinder and the inner surface of the cylindrical crucible. The internal diameter of the crucible is 1.75 Cm. The construction and dimensions are made clear in the figure. With this construction the temperature to which the vapor may be raised is limited by the melting temperature of lavite, which is in the neighborhood of 1525° C. A better material will be sought and selected for future work.

FIG. 2.



A small piece of metal, of which the vapor resistance is to be determined, is placed in the bottom of the graphite crucible and the temperature of the furnace is steadily increased (never being allowed to decrease while the measurement is in progress), and it is assumed that the metal in vaporizing expels all the CO + N gases which are formed within the crucible as soon as a red heat is attained.

It is recognized that when the pressure is atmospheric the quantity of metal which remains in the crucible after the original supply has all been vaporized is very minute, and that quantitative measurements, respecting the ratios of the conductivities of the vapors of different metals, will not have much meaning until means are provided for maintaining the metallic vapors under pressure. Furthermore, it is quite evident that when the temperature exceeds 1200° C. the interior of the graphite crucible is filled with minute particles of carbon intermingled with the metallic vapor, or CO + N gases when no metal is present. These minute particles of carbon may, and probably do, have a large part in the electrical conduction observed. A far better material out of which to construct a container would be a tube of pure metallic tungsten.

FIG. 3.

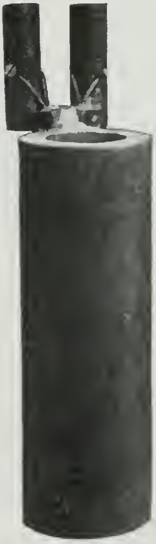
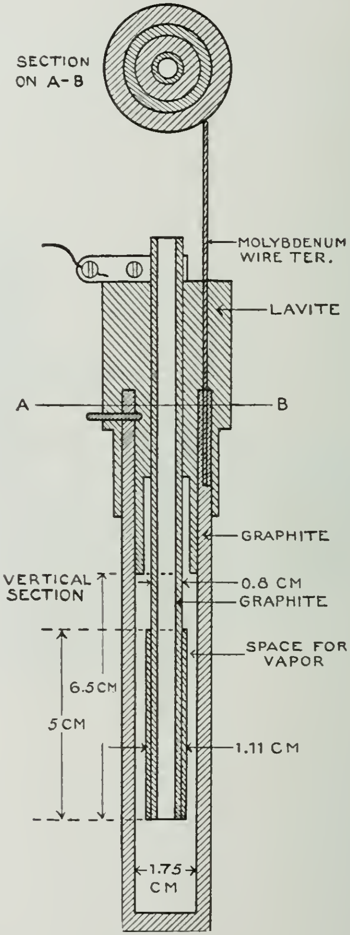


FIG. 4



The cost of this, however, has, for the time being, precluded its use. I do not consider, therefore, that the measurements so far made have any value in giving information respecting the relative conductivity of pure, uncontaminated metallic vapors. Nevertheless, the results obtained are satisfactorily accurate for a pure CO + N atmosphere filled with minute particles of carbon, and they reveal the general characteristics of the phenomena exhibited, which in some respects, to be pointed out, are extremely interesting.

Summarizing in respect to the apparatus, it may be said that the methods of producing and measuring the temperature are entirely satisfactory, and that the kinds of measurements which should be made for the discovery and interpretation of the phenomena have been quite clearly defined; but much work must be done in the design and construction of a suitable container and in means for maintaining the vapors under high pressure. The measurements thus far made must be considered as mere skirmish measurements, so to speak, made to discover the general character and drift of the phenomena.

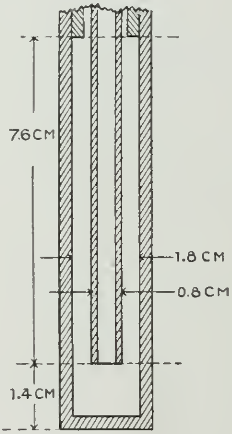
The Measurements.

If no metal is present in the graphite crucible, it may be assumed that when the temperature is above a red heat the oxygen of the air unites with the graphite to form CO, and that the atmosphere in the crucible is a mixture of carbon monoxide and nitrogen. If the temperature is raised to the neighborhood of 1500° C. there is added to this gas-mixture a certain quantity of very finely divided and chemically uncombined carbon. There are several lines of evidence that minutely divided carbon is present in the uncombined state. For example, refractory ware like marquardt porcelain placed in the crucible becomes very much blackened. The first measurements were planned to observe the characteristics of the electrical conduction of this gas.

Measurements of resistance were made using direct e.m.f., making the central cylinder alternately positive and negative, and also with alternating e.m.f. of 60 and 38 cycles. The several measurements I have made with alternating currents are, however, complicated and difficult to interpret and will not be included in this report.

Since it was thought that it might be desirable to reduce the resistance readings to specific values, the resistance was obtained of one of the containers, constructed with the same dimensions as were used in some of the gas-resistance measurements (see Fig. 4) when this was filled with a saturated solution of NaCl, having the known resistance of 4.425 ohms at 20° C. between opposite faces of a centimetre-cube of the solution. In obtaining this constant, contact resistance errors were largely avoided by first filling the container with mercury, the measured resistance in this case being due almost wholly to contact resistance. The result gave the net resistance of the container filled with saturated NaCl solution at 20° C. as about 0.2 ohm. The results obtained, using a fall of potential method and direct e.m.f.s, are given below. The diagrams and curves, with explanatory notes, which are here given, make clear the procedure and results without further description.

FIG. 5.

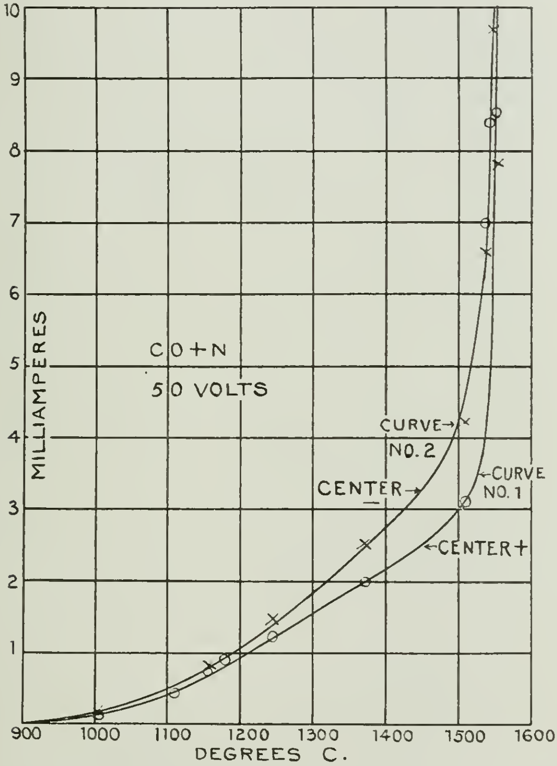


Volt-ampère Curve of CO + N. Measurement No. I.

The central cylinder of the container was given the same diameter throughout its length. The dimensions used in the measurements recorded in curves 1 and 2, Fig. 6, and 3 and 4, Fig. 7, are given in the cross-sectional diagram, Fig. 5. The connections employed are given in Fig. 8.

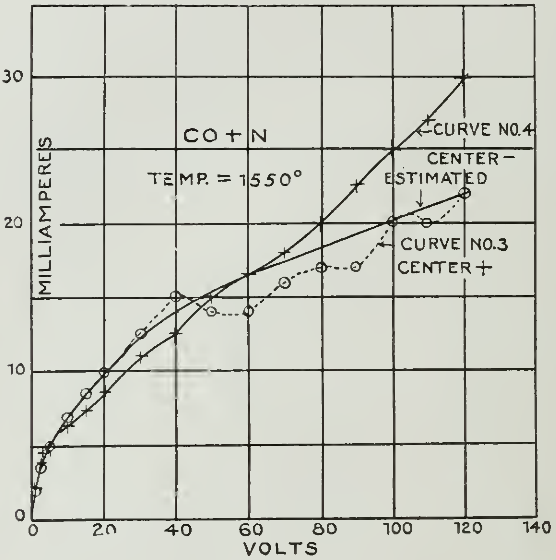
The procedure was as follows: The temperature of the furnace was raised very slowly; the furnace temperature was ascertained by reading the volts at the furnace terminals and the watts on the primary side of the transformer. The furnace resistance was calculated from the data, and the temperature was then taken from an experimentally gotten curve, previously obtained with much care. The e.m.f. at the electrodes of the container was maintained by means of the rheostat (Fig. 8) at exactly 50 volts.

FIG. 6.



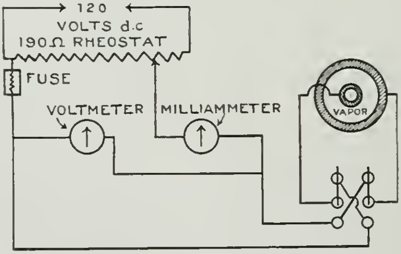
Readings of milliampères were made at frequent intervals, as the temperature slowly rose, alternate readings being taken, first with the center electrode made positive and then with this electrode negative. When the temperature had reached 1550° C. the furnace input was adjusted so that, as closely as possible, this temperature was maintained. Then, as quickly as possible, readings of milliampères were taken as the voltage was varied from 0 to 120 volts. The readings were taken with center electrode alternately positive and negative. The voltage was varied in steps of 1 volt from 0 to 5 volts, in steps of 5 volts from 5 to 20 volts, in steps of 10 volts from 20 to 120 volts.

FIG. 7.



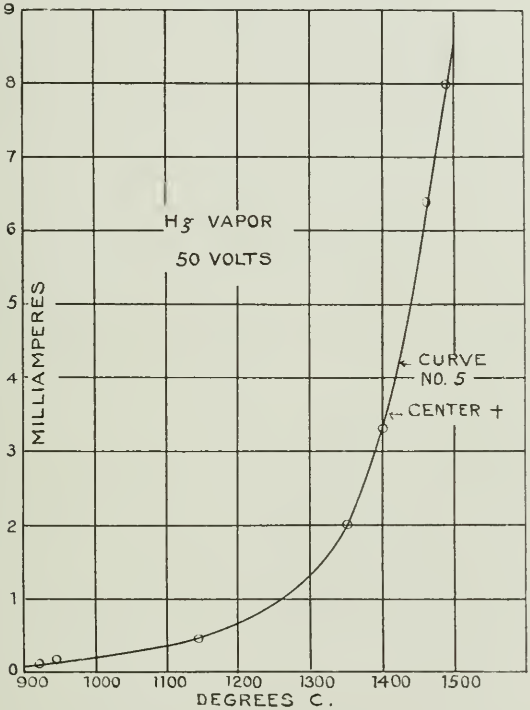
The results obtained are plotted in two sets of curves, the first (Nos. 1 and 2, Fig. 6) relating milliampères and degrees centigrade, the voltage being kept constant at 50 volts, the second

FIG. 8.



(Nos. 3 and 4, Fig. 7) relating milliampères and volts, the temperature being maintained constant at approximately 1550° C. After the furnace had cooled the container was examined and the lower end of the lavite top piece was found to show evidence of fusion. It is probable, therefore, that some vapors emanating from the lavite had contaminated the CO + N atmosphere at the highest temperatures. This may influence somewhat the absolute values obtained, but hardly, it is thought, the general shape of the curves Nos. 3 and 4, and not at all the shape of or absolute value of the curves Nos. 1 and 2 under the temperature of 1525° C., which is given by the Bureau of Standards as the fusion temperature of lavite.

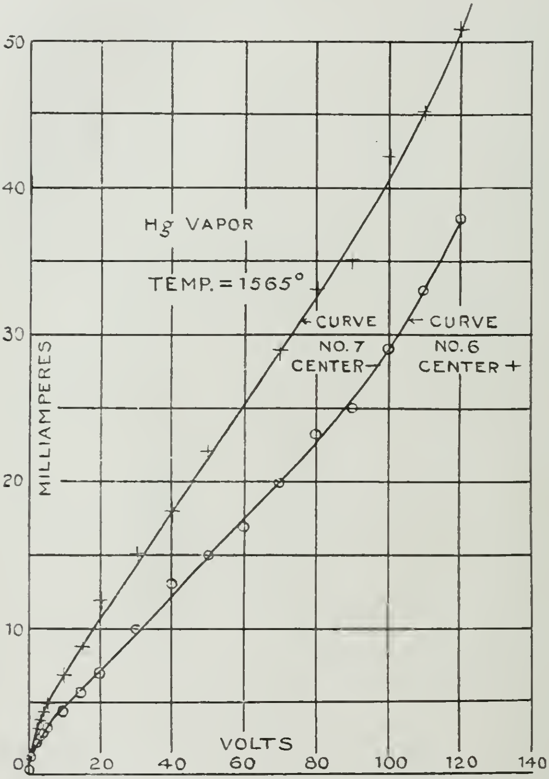
FIG. 9.



Volt-ampère Curve of Mercury Vapor. Measurement No. II.

Without any modification in the apparatus or method, curves were obtained when the crucible container was filled with the vapor of mercury. Before the furnace was heated a few grammes of mercury were placed in the container. To avoid a reëntrance of air into the container after the mercury had all become vaporized, a quartz tube was sealed into the top of the central graphite electrode. To the end of this a rubber tube was attached and bent into an S to form a trap for the mercury which distilled over. So long as the temperature of the furnace was rising or stationary it was assumed that no air could reënter the container. The curves (Nos. 5, 6, and 7) obtained in this case are given in Figs. 9 and 10. They have the same general character and magnitude as the curves for CO + N, but are more regular in form.

FIG. 10.



Measurement of the Asymmetric Resistance of Hot Gas. Measurement No. III.

It is quite apparent, from an examination of the data and curves, that the current passes, even between two electrodes of the same material but of different dimensions, more easily in one direction than in the other, and that the asymmetry changes sign with

FIG. 11.

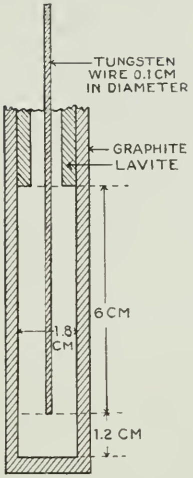
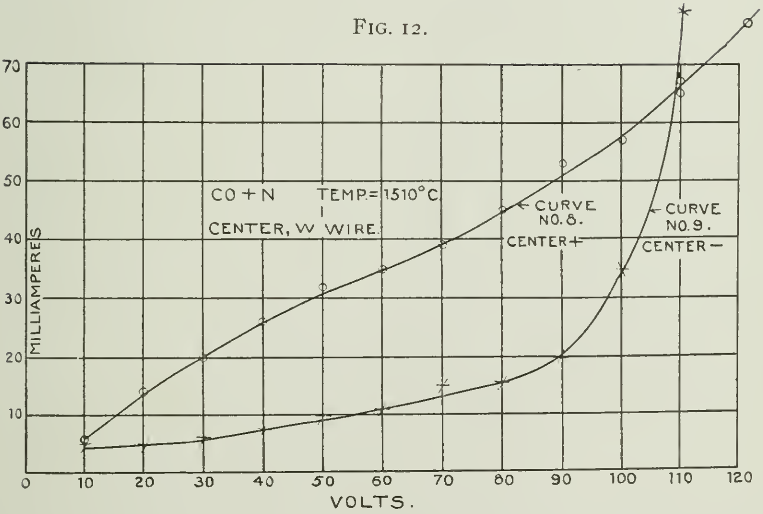


FIG. 12.



increase of voltage. To investigate this phenomenon further another set of measurements was taken with CO + N gases and the container fitted with a central electrode made of a tungsten wire 1 mm. in diameter. Fig. 11 gives a cross-sectional view with dimensions of the modified form of container used.

The temperature was successfully maintained constant during all the time that the readings were being taken, at 1510° C. The volts at the electrodes of the container were varied from 0 to 119 volts, and the corresponding milliampères were read as the central electrode of tungsten was made alternately positive and negative.

The data, as taken directly from note-book, and the plot of these data are given below in a table and in Fig. 12, curves 8 and 9.

December 23, 1914. Observers—E. F. Northrup and Mrs. E. F. Northrup.

Note.—Furnace heated until nickel melted (1452° C.). Temperature allowed to become steady at 1510° C. during measurement.

Volts at furnace terminals = 29.68, 29.8, 29.8.

Watts input = 1940, 1950, 1952.

Calculated furnace resistance at 1452° C. = 0.455_3 ohm.

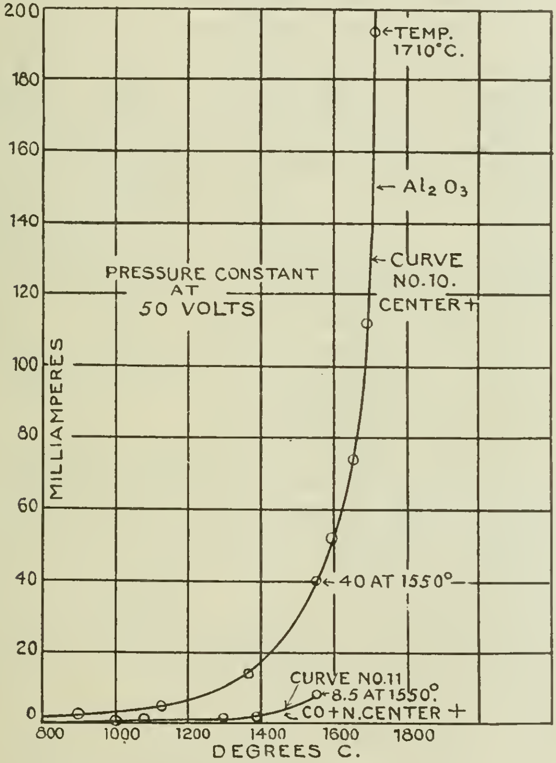
Pol'ty of W. Ter.	Applied volts	Milli-ampères	Furnace kilowatts	Furnace volts	Estimated furnace tempera-ture	Notes
			1.98	30.4	1510°	+ means current passes from tungsten to wall of cylinder through gas, and − means in reverse direction.
+	10	6	....	....	1510°	
−	10	5	....	....	1510°	
+	20	14	....	....	1510°	
−	20	5	1.96	30.4	1510°	
+	30	20	....	....	1510°	
−	30	6	....	....	1510°	
+	40	26	1.96	30.4	1510°	
−	40	7.5	....	....	1510°	
+	50	32	....	....	1510°	
−	50	10	1.94	30.2	1510°	$\rho = \frac{2.73RL}{\log_{10}\frac{b}{a}} = 13000\frac{\text{volts}}{\text{milliamp.}}$
+	60	35	....	....	1510°	
−	60	11	....	....	1510°	
+	70	39	1.96	30.2	1510°	$\rho = 23320$ ohms.
−	70	15	....	....	1510°	
+	80	45	....	....	1510°	
−	80	15.1	1.94	30.2	1510°	
+	90	53	1.94	30.4	1510°	Very steady, accurate point.
−	90	20	....	....	1510°	
+	100	57	....	....	1510°	
−	100	35	1.94	30.3	1510°	With long application of voltage reading slowly increased to 45 milliampères.
+	110	65	....	....	1510°	
−	110	75	....	....	1510°	
+	110	67	....	....	1510°	
+	119	75	1.92	30.2	1510°	Extra reading.

Note.—Above data plotted in curves Nos. 8 and 9.

Current vs. Temperature Curve of Pure Aluminum Oxide. Measurement No. IV.

The comparatively large current which, under a pressure of 50 volts, will pass through a mixture of hot CO + N gas, as shown by measurement No. 1, suggests the thought that the electrical conductivity found for all oxide powders and refractory materials at high temperatures may be due, in considerable measure, to the conductivity of the hot gases which permeate the solid material. Thus, if the space between the electrodes of an electrolytic cell were filled with wet sand, measurement would show a low resistance between the electrodes. One would not, however, conclude, from a measurement of the conductance between the electrodes, that the observed conductance is due to a conductivity of sand. Similarly, if all hot vapors and gases conduct, and all refractory materials are porous at high temperature, one cannot conclude that the conductivity of a refractory measured while immersed in a hot gas is only due to the conducting property of the material itself. To test this mater quantitatively a container of the same

FIG. 13.



form and dimensions as was employed in measurements Nos. I and II (see Fig. 5) was packed full of very pure, chemically-prepared Al_2O_3. Milliampères *vs.* degrees centigrade were measured, the pressure being 50 volts, and the center electrode maintained positive. The results obtained are given in curve No. 10, Fig. 13. The curve No. 1, Fig. 6, obtained with CO + N only in the container, taken under identically similar conditions, is replotted to the same scale in Fig. 13 (and is called curve No. 11) to give directly a comparison of the conductance of the gas only and of pure aluminum oxide powder with pores filled with gas. It will be noted that at 1550° C. 8.5 milliampères passed through the gas and 40 milliampères through the Al_2O_3 powder, the pressure in both cases being 50 volts with center electrode positive. Hence we may conclude that approximately 21 per cent. of the conductivity of the aluminum oxide is due to the conductivity of the hot gases in its interstices. In other words, even if the Al_2O_3 itself were a perfect insulator it is probable that a measurement, under the above conditions, would show it to have a conductivity approximately 21 per cent. of that actually found. It seems safe, therefore, to make the general statement that *when the temperature exceeds 1500° C. it is impossible to obtain even approximately good electrical insulation by any means.*

The data and curves given above suggest many lines of inquiry respecting the causes and nature of the conduction observed, and I have been led by them to make practical utilization of the conducting properties of hot gases and vapors for the production of excessively high temperatures. Other utilizations also of seeming importance are recorded in my notes and have been in part tried out. A description of these experiments as well as an analysis of the data given above must be reserved, however, for a later report.

High temperature investigation presents innumerable problems, and earnest quantitative work is sure to reveal new, interesting, and, very probably, commercially important results. It is, in my judgment, the most fruitful field for chemical and physical inquiry which is at this time presented to chemists and physicists.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

A STUDY OF SOME RECENT METHODS FOR THE DETERMINATION OF TOTAL SULPHUR IN RUBBER.

By J. B. Tuttle and A. Isaacs.

[ABSTRACT.]

THIS investigation was undertaken to learn whether or not the methods recently published for the determination of sulphur in rubber were any improvement over the Waters and Tuttle method, the one now in use at this Bureau.

The methods investigated were those of Spence and Young; Deussen, Alexander, the Joint Rubber Insulation Committee, Kaye and Sharp; Frank and Marckwald, and Waters and Tuttle. These were subdivided, according to the method of attack, into three classes: direct solution, direct fusion, and solution and fusion methods. A large number of determinations were made on a number of samples, two of the latter being of known composition which were specially prepared by one of the authors.

The methods which have been compared may be divided into two classes, viz., those for the determination of the total sulphur and those for the determination of sulphur other than that present in the insoluble sulphates. It was found that the methods of the second class could not be relied upon to give accurate results.

The direct solution methods, those of Spence and Young, and Deussen, involve the use of concentrated nitric acid. This was first suggested by Henriques, but is objectionable because it gives rise to low results.

The direct fusion methods, those of Alexander, the Joint Rubber Insulation Committee, and Kaye and Sharp, are reliable only when the free sulphur content is low, and are therefore not applicable to routine analysis.

The solution and fusion method of Frank and Marckwald was found to be unreliable when the free sulphur was high. The

---

* Communicated by the Bureau.

Waters and Tuttle method was found to give satisfactory results and recommended for general use.

A new suggestion is offered, namely, to determine separately the free sulphur and the sulphur remaining after the extraction, reporting the sum of the two quantities as the total sulphur. This procedure eliminates the troublesome effect of the free sulphur upon the determination of the total sulphur.

INVESTIGATION OF THE DURABILITY OF CEMENT DRAIN TILE IN ALKALI SOILS.*

[ABSTRACT.]

THE durability of cement mortar and concrete when exposed to concentrated alkali salts in soil and water has been questioned by many engineers and users of concrete. In the Western States many irrigation and other structures have been built of concrete in alkali soils, and cases of partial or complete failures of some of these structures have been attributed to the effect of alkali salts.

Laboratory investigations have shown that cement concrete is subject to disintegration by alkali salts under certain conditions, but practical experience has shown that some concretes are much less susceptible to the action of the salts than others and are quite permanent, even if exposed in very concentrated alkali soils. It was intended, in outlining this investigation, to make it an actual field test of practical, full-sized specimens composed of concrete of known composition, so that all conditions might be similar to those in which structures are exposed in the field.

In 1913 a committee, consisting of a representative from the United States Reclamation Service, the Drainage Division of the Department of Agriculture, the Association of American Portland Cement Manufacturers, and the Bureau of Standards, outlined a programme of tests to determine the effect of alkali on cement mortars of a known commercial quality. Since several millions of dollars are being spent annually in the drainage of alkali soils in the western part of the United States, and because of its economic

---

* By R. J. Wig and G. M. Williams in coöperation with S. H. McCrory, Drainage Division, Department of Agriculture, and L. R. Ferguson, Association of American Portland Cement Manufacturers, and E. C. Bebb, U. S. Reclamation Service.

importance, it was considered advisable to make observations on cement drain tile of known composition which would be exposed under normal service conditions in operating drains in concentrated alkali soils.

Over eight thousand cement drain tile, 12 inches long and 8 inches inside diameter, were manufactured in a commercial tile factory in Iowa during August and September, 1913. They included 16 different types, made up of mixtures from the leanest to the richest commercially practicable. Records were kept of all steps in the process of manufacture. Care was taken to produce a uniform and good quality of product, but no methods or materials were introduced which could not be reproduced in any well-equipped cement tile factory.

After all tile had cured for a period of at least one month shipments of a carload were made to projects in each of the following States: Colorado, Wyoming, Montana, Washington, Arizona, New Mexico, Utah, Minnesota, and Missouri.

The tile were installed in the first seven States in soils which contain large quantities of alkali salts and where concrete structures were thought to have been damaged by alkali action. The tile in Minnesota and Missouri were placed where they would be exposed only to fresh water, and a separate shipment was made to Ames, Iowa, where the tile were stored in the open above ground and exposed to the weather.

Installation was completed in November, 1913, and the tile were so arranged that sections at each project containing two tile of each series can be removed for test annually without disturbing the remainder of the line. Ten such sections were placed end to end at each project. Samples of soil, water, and alkali salts, where available, were secured for analysis.

The first year's tests were made in the fall of 1914. One section at each project, containing 32 tile, two of each series, was removed and tested at the site in a portable tile testing machine especially designed for the purpose. Samples of tested tile, as well as soil and water samples, were secured for chemical analysis. The tile removed for test were replaced with two other series of cement tile which were made for this purpose, and of which complete records of materials and methods were recorded. It is also planned to replace those tile removed for test during 1915 with additional cement tile manufactured by different methods.

CONCLUSION.

The details of this investigation and the results of the first year's tests are published at this time because of its economic value in demonstrating to those who are now using or considering using cement drain tile that special care should be observed to employ only the best materials and good workmanship in its fabrication, and if these precautions are not observed failure will result if the drain is located in some of the more concentrated alkali soils similar to those found at Grand Junction, Col., and Garland, Wyo.

Drain tile manufactured in a manner as herein described for series 2, 9, 10, 11, 13, and 15, of cement mixtures not leaner than one part cement to three parts of aggregate, are apparently unaffected structurally when exposed for one year in operating drains in very concentrated alkali soils, similar to any of those included in this investigation.

Drain tile made from cement mixtures leaner than one part cement to three parts of aggregate should not be used in localities where the character of the alkali and concentration is similar to that found at the site of the experimental drains at Grand Junction, Col.; Montrose, Col., and Garland, Wyo.

Drain tile manufactured in the manner herein described of one part cement to four parts of aggregrate, the leanest mixture used, is apparently unaffected structurally by exposure for one year in an operating drain in concentrated alkali soils similar to those found at Fort Shaw, Mont.; Sunnyside, Wash.; Yuma, Ariz., and Roswell, N. M.

Other than the above, no very general conclusions should be drawn from this investigation until the results of further tests are obtained. It is anticipated that this report will be amended from time to time as the results are available.

The Bureau would be pleased to receive information concerning the behavior of concrete exposed to concentrated alkali soil which may come to the attention of engineers or others interested in the use of concrete under these conditions.

THE FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting held Wednesday, February 17, 1915.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 17, 1915.

DR. GEORGE A. HOADLEY, *Temporary Chairman.*

Additions to membership since last report, 9.

Mr. George H. Clamer, chairman of the Committee on Science and the Arts, reported the condition of the committee's work.

The standing committees for the year 1914–15 were announced.

Dr. Francis D. Patterson, Director, Department of Sanitation and Accident Prevention, Harrison Brothers & Company, Inc., J. G. Brill Company, and the Electric Storage Battery Company of Philadelphia, presented an interesting communication on "Sanitation and Accident Prevention in Industry."

The campaign of education in accident prevention among the general public as well as among workmen was fully set forth and its importance upon the welfare of the community at large was pointed out. Attention was called to the necessity for guarding against accidents in the home, the workshop, and in public places, and the numerous devices now in use for the protection of workmen and others were described.

The importance of sanitation in factories with special relation to the prevention of occupational diseases was also given full consideration. The speaker illustrated the subject by numerous lantern slides and moving pictures. After a rising vote of thanks the meeting adjourned.

R. B. OWENS,
Secretary.

STANDING COMMITTEES, 1915.

OF THE BOARD.

ELECTIONS AND RESIGNATIONS.

W. C. L. Eglin,
Alfred W. Gibbs,
George R. Henderson,
R. S. Perry,
George D. Rosengarten.

ENDOWMENT.

James M. Dodge,
Alfred C. Harrison,
Henry Howson,
Richard Waln Meirs,
Coleman Sellers, Jr.

EXECUTIVE.

James M. Dodge,
Walton Forstall,
Alfred C. Harrison,
Richard Waln Meirs,
E. H. Sanborn.

INSTRUCTION.

George A. Hoadley,
Harry F. Keller,
Edward V. McCaffrey,
Lawrence T. Paul,
James S. Rogers.

SECTIONAL ARRANGEMENTS.

Charles Day,
Harry F. Keller,
Robert W. Lesley,
Louis E. Levy,
Lawrence T. Paul.

EXHIBITIONS.

John Birkinbine,
Francis T. Chambers,
E. Goldsmith,
C. A. Hexamer,
Marshall S. Morgan.

PUBLICATIONS.

John Birkinbine,
W. C. L. Eglin,
George A. Hoadley,
Louis E. Levy,
E. H. Sanborn.

STOCKS AND FINANCE.

Cyrus Borgner,
Walton Forstall,
Alfred C. Harrison,
Richard Waln Meirs,
E. H. Sanborn.

OF THE INSTITUTE.

LIBRARY.

Robert H. Bradbury,
Richard Gilpin,
Clarence A. Hall,
Harry F. Keller,
Gaetano Lanza,
Henry Leffmann,
Louis E. Levy,
Marshall S. Morgan,
George F. Stradling,
W. C. Wetherill.

MEETINGS.

Gellert Alleman,
G. S. Barrows,
G. H. Clamer,
George R. Henderson,
H. A. Hornor,
Herbert E. Ives,
M. M. Price,
James S. Rogers,
George D. Rosengarten,
Coleman Sellers, Jr.

MUSEUMS.

Henry F. Colvin,
Charles Day,
James M. Dodge,
Richard Gilpin,
George A. Hoadley,
Harry F. Keller,
Wilfred Lewis,
A. E. Outerbridge, Jr.,
Wm. H. Thorne,
Wm. J. Williams.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, February 3, 1915.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 3, 1915.

MR. GEORGE R. HENDERSON *in the Chair.*

Mr. G. H. Clamer was unanimously elected Chairman for the year 1915. The following report was presented for first reading:

No. 2586.—Dobbins's Daylight Rods.

The following reports were presented for final action:

No. 2614.—Hardinge Conical Ball and Pebble Mill. John Scott Legacy Medal and Premium recommendation to H. W. Hardinge adopted.

No. 2621.—Wahl Adding Machine. John Scott Legacy Medal and Premium recommendation to H. E. Goldberg and J. C. Wahl and Edward Longstreth Medal to Wahl Adding Machine Company adopted.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A stated meeting of the Section was held in the Hall of the Institute on Thursday, January 28, 1915, at 8 o'clock P.M., with Dr. Henry H. Donaldson in the chair. The minutes of the previous meeting were read and approved.

Dr. Donaldson introduced Ulric Dahlgren, Ph.D., Professor of Biology in Princeton University, who delivered a lecture on "The Production of Light by Animals." The wide distribution of light-producing organisms was demonstrated, and typical forms from the bacteria and fungi, and from several of the larger groups of the animal kingdom, were described. The anatomy and histology of the light-producing organs, including their reflectors, lenses, focusing devices, diaphragms, protective mantles, and colored screens, were discussed, as were the uses of the light for mating, protective and warning signals, and for illumination and ornamentation. The chemistry, physics, and physiology of the light production received attention, and an explanation was given of the different methods of oxygen supply and of internal and external combustion. The address concluded with remarks on the possibility of better light production by man. The lecture was illustrated by means of lantern slides and of luminescent bacteria and worms. After discussion of the paper the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday, February 4, 1915, at 8 o'clock

P.M., with Dr. Joseph P. Remington in the chair. The minutes of the previous meeting were read and approved.

Carl L. Alsberg, A.M., M.D., Chief of the Bureau of Chemistry of the U. S. Department of Agriculture, delivered an address on "Moisture in Agricultural Products." The quantity of moisture present in plant and animal tissues was discussed. The relation of the moisture content to the usefulness of a foodstuff, and its influence on spoilage were pointed out, as were certain other economic relationships, including the changes in water content during transportation and storage. An account was given of the relation of the moisture content of agricultural products to various industries.

The paper was discussed by Drs. Pennington, Remington, Keller, Miller, Pearson, Alsberg, and Mr. Bower. A vote of thanks was extended to Dr. Alsberg and the meeting adjourned.

Joseph S. Hepburn,
Secretary.

Electrical Section.—A joint meeting of the Section and of the Philadelphia Section of the American Institute of Electrical Engineers was held in the Hall of the Institute on Thursday evening, February 11, 1915, at 8 o'clock.

Mr. W. C. L. Eglin and Mr. H. V. Sanville presided jointly.

The minutes of the previous meeting were approved as published.

E. B. Rosa, Ph.D., Chief Physicist, Bureau of Standards, Washington, D. C., delivered an interesting and instructive lecture, entitled "Recent Researches in Electricity at the Bureau of Standards." In this lecture Dr. Rosa outlined the general plan of the buildings occupied by the Bureau of Standards, and then described particularly the arrangement and equipment of the Physics Building. With the aid of lantern slides he described recent work done at the Bureau in connection with electrical standards. He illustrated the nature of other researches in electrical engineering upon condensers, insulating materials, magnetic properties of steel rails, wireless telegraphy, and other subjects which have been undertaken at the Bureau, and for most of which special instruments and apparatus have had to be designed and constructed by members of the staff.

After a brief discussion, the thanks of the meeting were extended to the speaker.

Adjourned.

William E. Bullock,
Acting Secretary.

MEMBERSHIP NOTES.

(*Stated Meeting, Board of Managers, February 10, 1915.*)

ELECTIONS TO MEMBERSHIP.

RESIDENT.

Mr. Frank Gittelson, 1017 Spruce Street, Philadelphia, Pa.

Mr. William J. Turner, "Lycoming," School House Lane, Germantown, Philadelphia, Pa.

MR. S. D. WARRINER, 437 Chestnut Street, Philadelphia, Pa.

NON-RESIDENT.

MR. CHARLES EDWARD BENNETT, 59 West Twelfth Street, Atlanta, Ga.
MR. CHARLES A. TERRY, Westinghouse Electric and Manufacturing Company, 165 Broadway, New York, N. Y.

LIFE.

MR. CLARENCE E. CORNELIUS, 222 West Hortter Street, Germantown, Philadelphia, Pa.
MR. JOHN C. CORNELIUS, JR., 225 West Tulpehocken Street, Germantown, Philadelphia, Pa.
MR. JUSTICE C. CORNELIUS, 405 Wister Street, Germantown, Philadelphia, Pa.

ASSOCIATE.

MR. BARTRAM ASHMEAD OWEN, 411 Pine Street, Philadelphia, Pa.

CHANGES OF ADDRESS.

MR. J. J. GIBSON, care of Westinghouse Electric and Manufacturing Company, Box 911, East Pittsburgh, Pa.
DR. M. G. LLOYD, *Electrical Review and Western Electrician*, 608 South Dearborn Street, Room 1650, Chicago, Ill.
MR. JOSEPH T. MANNING, Thirty-seventh and Reed Streets, Philadelphia, Pa.
MR. TINIUS OLSEN, Hotel St. Francis, San Francisco, Cal.
MR. HENRY W. SCATTERGOOD, 530 Land Title Building, Philadelphia, Pa.
PROF. V. A. SUYDHAM, Medico-Chirurgical College, Philadelphia, Pa.

NECROLOGY.

Mr. J. B. Baker, Thirty-second Street and Powelton Avenue, Philadelphia, Pa., February 14, 1914.

Mr. J. Langcloth, P. O. Box 957, New York, N. Y., August 14, 1914.

LIBRARY NOTES.

PURCHASES.

DUBBEL, H.—High-Power Gas Engines. 1914.
GAGE, S. H. and H. P.—Optic Projection. Principles, Installation and Use of the Magic Lantern. 1914.
GREGORY, O.—Treatise on Mechanics—Theoretical, Practical and Descriptive. Three volumes. 1826.
HESS, H. D.—Graphics and Structural Design. 1913.
HUBBARD, C. L.—Power Heating and Ventilation. Two volumes. 1914.
JAMES, W. H., and DOLE, M. W.—Mechanism of Steam Engines. 1914.
LUNGE, GEORGE.—Technical Gas Analysis. 1914.

METCALF, L., and HARRISON, P. E.—American Sewerage Practice. Vol. i, Design of Sewers. 1914.

POISSON, S. D.—Traité de mecanique. Two volumes in one. 1811.

SHARP, JOHN.—Some Considerations Regarding Cast Iron and Steel Pipes. 1914.

SOUTH KENSINGTON SCIENCE MUSEUM.—Catalogue of the Mechanical Engineering Collection. Part 1, edition 5, and supplement. 1914.

VAN ORNUM, J. L.—Regulation of Rivers. 1914.

WAHL, A.—Manufacture of Organic Dyestuffs. 1914.

WRAIGHT, E. A.—Assaying in Theory and Practice. 1914.

GIFTS.

American Electrochemical Society, Transactions, 1914. South Bethlehem, 1915. (From the Society.)

American Institute of Electrical Engineers, Year-Book, 1915. New York, no date. (From the Institute.)

American Railway Master Mechanics' Association, Proceedings, vol. xlvii, parts i and ii. Chicago, 1914. (From the Association.)

British Aluminium Company, Ltd., Binder of Aluminium Publications. London, 1914. (From Mr. Arthur Seligman.)

Canada Department of Mines, Report, 1913: Report on the Building and Ornamental Stones of Canada, vol. iii. Ottawa, 1914. (From the Department.)

Canada Department of Trade and Commerce, Report, parts 2 and 3, 1914. Ottawa, 1915. (From the Department.)

Canada Public Archives, Report, 1913. Ottawa, 1914. (From the Public Archivist.)

Case School of Applied Science, Catalogue, 1914–1915. Cleveland, no date. (From the School.)

Central Electric Company, Catalogue No. 28. Chicago, 1912. (From the Company.)

Cutter Company, "When a Fuse Blows." Philadelphia, 1915. (From the Company.)

Goulds Manufacturing Company, Catalogue of Pumps. Seneca Falls, no date. (From the Company.)

Harvard University, Catalogue. Cambridge, 1915. (From the University.)

Illinois State Geological Survey, Bulletin No. 21. Urbana, 1914. (From the Survey.)

India Geological Survey, Memoirs, Series xv, vol. vii, Nos. 1 and 4. Calcutta, 1910. (From the Survey.)

Indian Meteorological Department, Rainfall Data of India, 1912. Calcutta, 1913. (From the Department.)

Iowa Geological Survey, Annual Report, 1912. Des Moines, 1914. (From the Survey.)

Iowa Railroad Commission, Thirty-sixth Annual Report. Des Moines, 1913. (From the Commission.)

Iron and Steel Institute, Journal, vol. xc. London, 1914. (From the Institute.)

Isthmian Canal Commission, Canal Record, vol. vii. Ancon, 1914. (From the Commission.)

IXL Pump and Manufacturing Company, Catalogue "C." Philadelphia, no date. (From the Company.)

K. Vitterhets Historie Och Antikvitets Akademien, Fornvannen, 1913. Stockholm, 1914. (From the Akademien.)

Lake Superior Mining Institute, Proceedings. Ishpeming, 1914. (From the Institute.)

MacArthur Concrete Pile and Foundation Company, "Concrete Pile Standards." New York, 1915. (From Mr. Hunley Abbott.)

Message of the Governor of Pennsylvania to General Assembly, January 5, 1915. Harrisburg, 1915. (From the State Librarian.)

Minneapolis Steel and Machinery Company, Catalogue B201. Minneapolis, no date. (From the Company.)

Missouri Botanical Garden, Annals, vols. 1–4. St. Louis, 1914. (From the Botanical Garden.)

Montana Railroad and Public Service Commission, Seventh Annual Report. Helena, 1914. (From the Commission.)

Mount Holyoke College Catalogue. South Hadley, 1914. (From the College.)

Murray Iron Works, Pamphlet No. 12. Burlington, no date. (From the Company.)

National India Rubber Company, Catalogue of Insulated Wires and Cables. Bristol, no date. (From the Company.)

National Machinery Company, Catalogue E. Tiffin, no date. (From the Company.)

New Process Twist Drill Company, Catalogue of Drills. Taunton, 1915. (From the Company.)

New South Wales Vital Statistics for 1913. Sydney, 1914. (From the Government Statistician.)

New York General Education Board, An Account of its Activities, 1902–1914. New York, 1915. (From the Board.)

New York Public Service Commission, Report, vol. i, 1913. Albany, 1914. (From the Commission.)

Oklahoma Geological Survey, Bulletins Nos. 13, 18, 21, 22. Norman, 1914. (From the Survey.)

Pennsylvania Board of Public Charities and Committee on Lunacy, Report, 1913. Harrisburg, 1914. (From the State Librarian.)

Pennsylvania Commissioner of Banking, Nineteenth Annual Report, part 2, 1913. Harrisburg, 1914. (From the State Librarian.)

Pennsylvania Commissioner of Health, Annual Report. Harrisburg, 1910. (From the State Librarian.)

Pennsylvania Department of Agriculture, Report, 1913. Harrisburg, 1914. (From the State Librarian.)

Pennsylvania Department of Mines, Reports, parts 1 and 2, 1913. Harrisburg, 1914. (From the State Librarian.)

Pennsylvania Secretary of Internal Affairs, Annual Report, parts 1 and 2, 1913. Harrisburg, 1914. (From the State Librarian.)

Pratt Institute, Catalogue, 1913–1914. Brooklyn, no date. (From the Institute.)

Princeton University Observatory, Contribution No. 3, "A Study of the Orbits of Eclipsing Binaries." Princeton, 1915. (From the Observatory.)

Smithsonian Institution, Annual Report, 1913. Washington, 1914. (From the Institution.)

Sturtevant, B. F., Company, Catalogue No. 195. Boston, 1914. (From the Company.)

Tasmania Department of Mines, Geological Survey Bulletin No. 18. Tasmania, 1914. (From the Department.)

Thomas, R., and Sons Company, Catalogue No. 12. East Liverpool, no date. (From the Company.)

United States National Museum, Report, 1914. Washington, 1915. (From the Museum.)

United States Surgeon-General's Office, Index-Catalogue of The Library, Second Series, vol. xix. Washington, 1914. (From the Surgeon-General.)

University of Pennsylvania, Catalogue. Philadelphia, 1914. (From the University.)

Verona Tool Works, Catalogue No. 11. Chicago, no date. (From the Company.)

Washington Public Service Commission, Fourth Annual Report. Olympia, 1914. (From the Commission.)

Wesleyan University, Catalogue. Middletown, 1915. (From the University.)

Wiley & Russell Manufacturing Company, Catalogue No. 36. Greenfield, 1914. (From the Company.)

BOOK NOTICES.

IOWA STATE UNIVERSITY, BULLETIN, NEW SERIES NO. 87. University Extension Bulletin No. 8. Bureau of Municipal Information. Water Works Statistics of Thirty-eight Cities of Iowa, with the Meter Rates of Seventy Cities. By John H. Dunlap. Iowa City, University. 52 pages, 8vo.

The administration of American municipalities is the despair of efficiency engineers, and in no respect is the difficulty greater than in the control of water supply. American communities are notorious water-wasters, and privilege and silly sentimentality ("water should be as free as air") interfere with business methods. Data such as are included in this pamphlet will be of use in presenting correct notions. H. L.

MODERN INSTRUMENTS AND METHODS OF CALCULATION. A handbook of the Napier Tercentenary Exhibition. Edited by E. M. Horsburgh. Pp. vii and 343. Illustrations. 8vo. London: G. Bell and Sons, Ltd., and The Royal Society of Edinburgh. No date. Price, 6s. net.

The valuable collection of mathematical books, tables, and instruments available for inspection at the Napier Tercentary Exhibition, held by The Royal Society of Edinburgh to celebrate the three hundredth anniversary of the publication by John Napier of his Canon of Logarithms, forms the basis of construction of this book. The first chapter deals with the life and inventions of Napier himself, and there follow two sections made up of catalogues of the exhibition. The major part of the book contains articles by specialists on calculating machines, the abacus, slide rules, and other mathematical laboratory instruments, including integraphs, planimeters, harmonic analyzers, and a tide predicter. Chapters on ruled papers, nomograms, and mathematical models conclude the work. The chapters relating to calculating mechanisms include the latest form of adding and listing machines and adding and subtracting typewriters. The book is of value to all who are interested in mechanical calculation.

W. E. BULLOCK.

PUBLICATIONS RECEIVED.

Annuaire pour l'an 1915 publié par le Bureau des Longitudes, Avec une notice scientifique. 995 pages, illustrations, maps, 24mo. Paris, Gauthier-Villars, no date. Price, 1 franc 50c.

Canada Department of Mines, Mines Branch: Production of Cement, Lime, Clay Products, Stone, and Other Structural Materials in Canada during the Calendar Year 1913. 62 pages, 8vo. Production of Iron and Steel in Canada during the Calendar Year 1913. 44 pages, 8vo. Ottawa, Government Printing Bureau, 1914.

U. S. Bureau of Mines: Monthly Statement of Coal-mine Fatalities in the United States, October, 1914, with revised figures for preceding months. Compiled by Albert H. Fay. Washington, Government Printing Office, 1915.

Density of Wood Substance and Porosity of Wood, by Frederick Dunlap, Forest Assistant, Forest Products Laboratory, Forest Service. Reprint from *Journal of Agricultural Research.* 6 pages, 8vo. Washington, Department of Agriculture, 1914.

Leavening Agents: Yeast, Leaven, Salt-raising Fermentation, Baking Powder, Aërated Bread, Milk Powder, by Richard N. Hart, B.S. 90 pages, illustrations, 8vo. Easton, Pa., The Chemical Publishing Company, 1914. Price, $1.

Potassium Oxide in California. ANON. (*Oil, Paint, and Drug Rep.,* Sept. 7, 1914.)—The first American potash will be produced by the Searles Lake plant within three months. The initial output will be only about 5 tons per day, but the plant under construction is expected to produce 120 tons per day.

CURRENT TOPICS.

Use of Pulverized Coal in the Cement Industry. R. C. CARPENTER. (*Amer. Soc. Mech. Engin. Journal,* xxxvi, p. 337.)—The author devotes a large portion of this paper to the history of the development of the process for burning pulverized fuel in cement kilns in the United States. Hurry and Seaman were the first to apply the new method successfully, in the years 1894–95, in the cement works of the Atlas Company. According to the author no inventors prior to Hurry and Seaman had comprehended the essential condition of success for burning pulverized fuel in furnaces; namely, that the fuel must be burned completely while in suspension, and that the utilization of the heat of combustion must be by radiation from the flame, and not by impingement of the flame on the bridge or walls of the furnace. The failure to recognize this condition of success is, he states, in a large measure responsible for the practical failure of the burning of pulverized fuel in boiler furnaces, although such furnaces, because of their form and proportions, render more difficult the problem of burning coal-dust in suspension. In practically all of the devices which have been tried under boilers the flame has impinged on the bridge-walls or sides of the furnace, or on portions of the boiler, before the combustion was completed, with the results that fuel was wasted, capacity was reduced, and the linings of the fire-box or other portions on which the flame impinged were destroyed. Since 1902 the use of pulverized coal for heating the rotary kilns has become general in the cement industry, and operations and machinery used have become standardized. They are considered and described under the following headings: (1) Drying; (2) Pulverizing; (3) Conveying; (4) Storing; (5) Feeding.

An Ideal Rubber Factory. A. DOUGLAS. (*India Rubber Journ.,* xlviii, 18.)—The greatest possible cleanliness must be aimed at, and certain precautions in factory-design and equipment are enumerated. There must be no bright light, which darkens the rubber, and no dark corners to harbor fungi. Rain water should be collected and used for dilution of latex and acid. Smoke chambers should be of wood, with heavy corrugated iron roofs, lined with sacking. The procedure recommended for the production of smoked sheets is as follows: The latex is diluted to standard gravity and mixed in a white-tiled tank. From 0.7 to 1 per cent. of its bulk of 10 per cent. acetic acid is added, and the mixture stirred with a glass rod, and then transferred in pails to the pans, which, when full, are skimmed and dividing boards introduced. On the following morning the coagulum is gently pressed until about three-fourths of an inch thick, then reduced to ordinary sheet thickness by three or four passages through smooth rollers, and finally once through marking rollers. The sheet is drained on racks for two hours, then smoked. Decayed timber and cocoanut husks form good fuel. The rubber is ready to pack in ten days. In making thick crépe the rubber is first sheeted between rollers, dried, and re-rolled thick in diamond rollers and dried further. It is ready for packing in twenty-one days.

The Influence of Allotropy on the Metastability of Metals, and its Bearing on Chemistry, Physics and Technology. E. COHEN. (*Faraday Society,* Nov. 23, 1914.)—Experiments made with pure cadmium are described, measurements being made with the pyknometer, the dilatometer, and with low-voltage standard cells in which the negative electrode consisted of cadmium deposited electrolytically on a platinum spiral. The results show that ordinary cadmium contains three allotropic forms. Density and dilatometric measurements made with pure lead indicated for this metal also the simultaneous presence of more than two allotropic forms. The conclusion is drawn that the pure metals (Cd, Pb, Bi, Cu, Zn, Sb), as known until now, are metastable systems consisting of two (or more) allotropic forms. This is a consequence of the very strongly marked retardation which accompanies the reversible change of these allotropic modifications below and above their transition points. All the physical and mechanical constants of metal hitherto determined thus refer to complicated metastable systems, which are entirely undefined, as the quantities of the α, β and γ modifications they contain are not known. The reversible transformations of one modification to another must play an important rôle when metals are subjected to changes of temperature. If the metals are in contact with electrolytes (water), the transformation velocity is enormously accelerated, and the volume changes which generally accompany these transformations may cause the disintegration of the metals. These phenomena must be taken into account in cases where corrosion occurs.

Martensite Structure of Steel. C. H. DESCH. (*Faraday Society,* Nov., 1914.)—By slowly cooling an overheated steel (C 0.28 per cent.) a martensitic structure was obtained without increase of hardness; by examination with an immersion objective, the whole mass was found to consist of pearlite packed closely in some parts and loosely in others. The view of Edwards and Carpenter that martensite and austenite are constitutionally identical, the former being repeatedly twinned, and its hardness due to the formation of amorphous material at the surface of slip on which twinning occurs, is rejected, and it is considered that the martensitic structure is an accompaniment, and not the cause, of the hardness of a quenched steel, martensite being so much harder than its components as to suggest the presence of a solid solution.

Interstrain Theory of Hardness of Metals. A. McCANCE. (*Faraday Society,* Nov., 1914.)—Pure iron, like other metals, is hardened when strained so as to cause permanent deformation. The iron is then in a condition of "interstrain," in which the arrangement of the atoms in the original crystalline structure is so far disturbed that the atoms can no longer return to their positions of equilibrium, and it is this condition which is considered to involve increased hardness; under strain α-iron remains magnetic and γ-iron non-magnetic, showing that the metal is not merely reduced to an amorphous structure by strain, but retains the distinguishing properties which are the result of crystalline form. To harden steel by quenching, it must be heated to the temperature at which the carbon is all in solution, and the greatest hardness is obtained when the temperature reaches the highest change point. The maximum hardness is obtained with C 0.7 per cent.; since the hardness is not proportional to the amount of carbon dissolved, the action of the carbon is indirect. Steel, which is non-magnetic at the temperature of quenching, becomes magnetic in the hardened state, owing to the conversion of γ- into α-iron. With a given rate of cooling this change of crystalline structure stops at a point determined by the increase in the internal viscosity at the lower temperature, and in this way a condition of interstrain is produced involving increased hardness. Tempering removes the condition of interstrain.

America's Mineral Products.—The mineral products of the United States are discussed in a small volume now being distributed by the United States Geological Survey which contains a fund of useful information concerning the useful minerals and their values and production in all the States during 1912 and 1913. The figures given in some of the tables are so stupendous as to be beyond comprehension. In one table are given the figures for mineral production from 1880 to 1913, the metals being valued at $185,000,000 in 1880 and increasing to $883,000,000 in 1913. The nonmetallic minerals increased from $173,000,000 in 1880 to $1,562,000,000 in 1913, and the total mineral production from $365,000,000 to $2,446,000,000. This total for 1913 was an increase over 1912 of more than $200,000,000. The value of the metals imported for consumption in 1913 was $237,000,000 and of those exported $319,000,000. The value of the total mineral production from 1880 to 1913, inclusive, was $35,197,000,000.

These huge figures are of general interest, but the chief value of the volume lies in the figures and discussion of the increased or decreased production of each State during recent years. Seventy principal minerals are discused in the pamphlet, entitled "Mineral Products of the United States in 1912 and 1913," a copy of which may be obtained free of charge from the Director, U. S. Geological Survey, Washington, D. C.

The Theory of Bleaching. S. H. HIGGINS. (*J. Soc. Dyers and Col.,* xxx, 326.)—The bleaching action of hypochlorous acid is due initially to the direct production of oxygen, but, as the bleaching proceeds, hydrochloric acid accumulates and reacts with hypochlorous acid according to the equation, $HOCl + HCl = H_2O + Cl_2$. This action is reversible, the reverse direction representing the behavior of chlorine water, and in each case when equilibrium occurs the bleaching action ceases. When a hypochlorite is used for bleaching, the hypochloric acid produced is used in liberating more hypochlorous acid. The removal of free hydrochloric acid from either chlorine water or hypochlorous acid by addition of calcium carbonate has been shown experimentally to accelerate the bleaching action. Taylor's observation that there is always a certain amount of residual color in cotton treated with hypochlorous acid or chlorine water is explained by this state of equilibrium; when calcium carbonate is added, the cotton is completely bleached. The coloring matters of brown linen and of boiled cotton are at once partially bleached on immersion in chlorine water, but prolonged treatment has very little further effect. The action of bleaching powder solutions on cotton dyed with direct and basic dyestuffs has been examined; in a number of cases the solutions to which hydrochloric acid was added caused a change of color, while when boric acid was added no such change was observed. In the majority of cases the solutions containing hydrochloric acid had the more rapid bleaching action; with alizarin sapphirole, however, the reverse was the case. The author concludes that the bleaching action of hypochlorites is due to the direct production of oxygen and to the production of nascent chlorine. Thus, it has been found that a large quantity of acetaldehyde is produced on warming dry calcium hypochlorite with alcohol, while it is known that bleaching powder can convert alcohol into chloroform. It is considered that the nascent chlorine is formed by the interaction of the chloride with the free hypochlorous acid. The effect of the calcium chloride produced during bleaching with bleaching powder is shown to be negligible, but when calcium chloride is added during the bleaching process it always has a stimulating effect, showing that hypochlorous acid is present during the whole process. Attention is drawn to the importance of using carefully-prepared fibre in bleaching experiments, and of making allowance for the fact that the coloring matters of cotton and linen are of an acid nature, especially in comparing the bleaching actions of acid and alkaline solutions.

Italian Petroliferous Zone. B. GALDI. (*L. Ind. Chimica. Min. e Metall.,* i, 264.)—The petroleum industry in the province of Emilia has worked successfully with a moderate profit, and systematic prospecting for petroleum throughout the whole of southern Italy is now recommended.

The Sale of Tar. (*Chem. Trade J.*, Nov., 1914.)—The following conditions relative to the sale of tar have been agreed upon by the joint committee of the Institution of Gas Engineers representing tar producers and distillers, and are recommended for adoption throughout the United Kingdom:

I. *Sliding-scale Contracts.*—(*a*) The tar distillers and gas authorities, or their valuers, to meet each month as usual, to fix the values of the products other than pitch. (*b*) The tar distillers to pay to the tar producers the aggregate value of such products, *plus* 2s. 6d. per ton of tar on account, for the pitch, less the usual 2½ per cent. and working expenses. (*c*) All pitch made and delivered since August 1, 1914, by individual tar distillers during the period of crisis to be paid for each month *pro rata* to the deliveries of tar of each producer, allowance being made for the 2s. 6d. per ton of tar already paid on account. (*d*) On the resumption of the export of pitch at present suspended, the value of such pitch delivered each month to be settled by the usual arbitrators, and the value ascertained each month to be added to the tar values and paid by the tar distillers to the tar producers, less the 2s. 6d. per ton of tar already paid on account. (*e*) The additional cost (if any) incurred by the removal and storage of pitch to be equally borne by the tar producers and the tar distillers.

II. *Price-fixed Contracts.*—(*a*) The sum of 17s. 6d. per ton of tar to be paid by the distillers and accepted by the producers in part payment as the value of products other than pitch and part value of pitch. (*b*) The balance to be paid as and when the pitch is delivered by the distillers *pro rata* to the deliveries of tar of each producer.

III. *Minimum Price of Pitch.*—A committee has been appointed to consider and, if advisable, to fix prices from time to time.

IV. *Revision of Conditions.*—These conditions may be amended by mutual arrangement between the tar producers' committee and the tar distillers from time to time.

The Veritas Firing Rings as Pyrometers. A. V. BLEININGER and G. H. BROWN. (*Trans. Amer. Ceram. Soc.*, xvi, 222.)—The principle involved in the use of these rings, invented by M. Solon, is the same as in the pyrometer devised by Josiah Wedgwood: that of shrinkage in fire. A clay body similar in composition to white ware (roughly, clay 52, flint 33, felspar 15 per cent.) is formed into rings 2.5 inches in diameter, with a hole 0.85 inch diameter. Progress of firing is followed by the withdrawal of rings from various parts of the kiln. The rings share the properties and defects of Seger cones, but are more useful in the early stages of the fire, as they swell up before dehydration, whereas a cone shows nothing until incipient softening by fusion occurs. Rings of a former batch should be preserved in order to check the behavior of the next batch.

The True Value of Sodium Perborate Bleaching. W. KIND. (*Z. Ges. Textil. Ind.*, xvi, 1045.)—Although the perborate cannot compete with the chlorine bleach on the ground of cost, yet it has advantages over hydrogen peroxide, mainly on account of the ease with which a solution of the required strength can be made up and the way in which it gradually gives up its oxygen without the development of too great a degree of alkalinity. Perborate has advantages for special purposes in bleaching, *e.g.*, for colored and finished goods. As a starch remover it can compete in certain circumstances with "Diastafor." It destroys active chlorine, but not chloramines. In dyeing it is used for after-treating vat and sulphide dyes, in cleaning for removing stains and for bleaching feathers, etc. It has found its greatest application in the laundry on account of being safer than the chlorine bleach. Generally its use in ordinary bleaching is too expensive.

Applications of Tar and its Derivatives. KAYSER. (*J. Gasbeleucht*, lvii, 200.)—Owing to the large amount of benzene for use in dye manufacture recovered in the production of coke in coke-ovens, new outlets are necessary for the tar and its derivatives produced in gas works. The use of tar oil as fuel in furnaces and engines is one such. In furnaces the oil should be supplied under pressure and then broken up by air streams. A flat stream issuing under low pressure appears better than spraying through easily-choked, fine orifices. In the Irinyi apparatus the oil is vaporized in a retort in the furnace, oil flowing to the retort by gravity. The advantages of tar-oil in furnaces are smokeless firing, simplicity of working, and cheapness. Tar oil is also used in Diesel engines, and Körtings's have a plant of 500 horse-power running with tar from vertical retorts; this works as well as a tar oil installation, while the cost of fuel is less, but a special starting means is necessary. Tar has also been used in furnaces. Tar is in demand for road making and for coating wood, etc., especially in roof work. Pitch is used in the coal briquetting industry. Separate works for the distillation of 175 to 200 tons of tar per annum are not profitable. Combined working of such outputs should be resorted to. Both continuous and discontinuous distillation processes are used. A continuous plant of H. Hirzel comprises a raised reservoir into which tar is pumped, and whence it flows through a vertical chamber having horizontal baffles and heated to 180° C. to drive off water and light oils. It then passes through a series of three stills, placed side by side and stepwise. In the first medium oils are driven off; in the second, heavy oils, and in the third, anthracene, the pitch being drawn off through a cooler into pits. The distillates are passed through condensers into reservoirs. A fourth still is used alternatively as the third in the series, and alternate cooling tanks are used for the pitch. In the discontinuous process a vertical retort is usual, the means for driving off water and light oils being the same as in the continuous process. For large plants a vacuum process is desirable. In the Sadewasser system, tar in a continuous stream is passed through a superheater and sprayed in a vacuum chamber; the ensuing vapor is condensed in fractional cooling chambers. Pitch is suggested as an alternative to cement for building purposes.

Effects of Pressure on Distillation of Hardwood. R. C. PALMER. (*J. Ind. Eng. Chem.*, vi, 890.)—Experiments were made with maple and birch sawdust and birch chips 1 × 1/8 × 1/8 inch in size, distillation being effected in a cast-iron autoclave, 15¼ inches deep by 8¼ inches inside diameter. The effect of pressure was to increase the yield of charcoal and gas and, to a slight extent, of wood alcohol, and to decrease the yield of acetic acid, pyroligneous acid, and tar. A greater effect was produced by increasing the pressure from atmospheric to 60 pounds than by a further increase. The greatest effect was on the yield of tar, which was decreased 60 to 65 per cent. at 60 pounds pressure. It is suggested that possibly pyroligneous acid free from soluble tar might be obtained by subjecting the distillate to high pressure during the vapor stage.

Comparison of Engler's and Barbey's Viscosimeters. C. BAHEUX. (*Les Matières Grasses*, vi, 3221.)—Barbey's ixometer measures the fluidity of an oil, but does not give information of the behavior of a lubricating oil in practice. In the case of machine oils, whose fluidity is usually determined at 35° and 50° C., the results are concordant, but for testing cylinder oils (100° C.) Engler's viscosimeter is preferable, since less time is required. Moreover, the use of an oil-bath with the ixometer involves considerable error due to the irregular distribution of the heat, whereas the heating bath of Engler's apparatus is easily regulated. The values obtained with the two apparatuses do not agree in all cases, the friction coefficient being greater in the case of Barbey's apparatus, which has a much longer outlet tube. Of two oils with equal viscosity, that with the smaller friction coefficient will pass more readily through the outlet tube of Barbey's apparatus than the other. This is particularly noticeable with compound oils, the friction coefficient of which is lower than that of mineral oils of equal viscosity. Only mineral oils of the same viscosity that have been refined, etc., in the same way can be compared by means of Barbey's apparatus. Engler degrees may be calculated into Barbey's degrees by the formula: $f = \frac{720,000}{v. a. M.}$ where f represents the Barbey fluidity degree, v the Engler viscosity, a the efflux velocity (seconds in Engler's viscosimeter) of 200 c.c. of water at 20° C., and M a factor varying with the temperature and the quality of the oils. The results agree well in the case of mineral oils at 50° and 100° C., but are not applicable without correction to oils tested at 35° C., or to compound oils.

The Auto Truck on Geodetic Work.—An unusual feature of the work of the United States Coast and Geodetic Survey, Department of Commerce, during the past summer was the successful use of a 1½-ton automobile truck in transporting an astronomical party and outfit through a portion of the Southwest which is generally dreaded by the transcontinental tourist. The party was in charge of Mr. C. V. Hodgson and was in the field from May to October. The trip is the more remarkable when the fact is taken into consideration that the requirements of the work prevented a close adherence to the routes usually followed. Observations were frequently made on mountain peaks, so the journey was from mountain to mountain, rather than along main travelled roads from city to city.

The general route followed by Mr. Hodgson and his party was from Denver, Colo., to Pecos, Texas, then southwest almost to El Paso, where a detour was made over poor trails through southern New Mexico into Arizona. The central and southern portions of the latter State were rather well covered, the itinerary including Solomonsville, Douglas, Benson, Tucson, Globe, Phœnix, Yuma, and Parker. The auto truck was then driven across California to San Diego and the San Jacinto Mountains, thence via Los Angeles, Mojave, and Sacramento to Carson City, Nev. Astronomical observations were carried along the California-Nevada boundary to Needles, Cal., the terminus of the journey. During the season the truck, carrying a capacity load, was run more than 5000 miles under road conditions varying from the deep mud encountered in New Mexico and Texas, and the heavy sands of the Colorado River and Nevada desert regions, to the splendid roads of southern and central California.

On a canyon road in western Texas Mr. Hodgson's party and outfit had a narrow escape when a small cloudburst in a few minutes transformed the road into a river, as the water came rushing down the canyon from the mountains above. There was no time to put on chains, but ropes were quickly wrapped around the rear wheels and the truck was run up a steep slope until stalled in the rising and rushing water. The truck was then moored to mesquite bushes and the outcome awaited with considerable anxiety, but the water soon ceased to rise and the danger was past. Had the truck remained where the water first struck it, it would have been almost completely submerged and probably overturned and damaged by the drifting timbers.

It was in the desert sands, however, that the greatest difficulties were encountered, as the truck was fitted with ordinary solid rubber tires (dual behind) which cut in deeply. Many expedients were tried, but the most successful one was the use of green poles placed in front of the dual-tired rear wheels in as rapid succession as possible. These poles gave traction and kept the wheels from sinking into the sand. The extreme heat, often reaching 115° in the shade, made such work very trying.

The cost sheets of the season show that the work was done at a saving of at least 35 per cent. from the cost had teams been used. The cost per mile for oil and gas varied from 2.7 cents to 6.6 cents in different sections of the country, and averaged 3.9 cents for the entire season.

A remarkable feature of the performance of the truck and a tribute to the good work of the driver was the fact that, from the time of leaving Colorado Springs to the end of the season, about six months, during which the truck was run over 5000 miles, only two hours were lost on the road on account of engine troubles.

Corrosive Action of Electrical Currents on the Gas and Water Mains in the Town of Gablenz a. N. (Austria). T. HERRMANN. (*J. Gasbeleucht,* lvii, 88.)—Attention is drawn to the serious electrolytic corrosion of water and gas mains in Gablenz. The origin of the earth currents is attributed to the electric tramways in the streets. These vagrant currents are assisted by impurities introduced into the soil through acids formerly discharged by factories in various places. The damaged pipes are for the most part situated under the tram rails, and cast- and wrought-iron tubes were equally attacked. In a large number of lead pipes the metal was transformed into a brown powder, whereby serious leaks of gas occurred. The accumulation of gas led, in one instance, to a disastrous explosion. Especial damage has been caused at the gas works, where many lines converge, through stray currents travelling along the main pipes connected with the plant. The water conduits and oil pumps were thus destroyed. Accidents also arose from the difference in potential existing between the earthed gas plant and the tram rails, which led to discharges between the two. In addition to electrolytic actions, a number of accidents have arisen through lightning discharges. These have struck the overhead live wires, or, in some cases, exposed metal fittings, and created a short circuit between the electrical leads and the gas mains or telephone wires. The disturbances at the gas works have been obviated by suspending electrical traction altogether and by interrupting the metallic connection between the street mains and the gas works. This has been effected by the use of flanged joints between the pipes, packed with layers of mica. This method has introduced an additional danger on account of lightning discharges. Electrical charges concentrated in the ground surrounding the works tend to pass along the whole length of pipes as offering the path of least resistance to distribution in the earth; currents thus tend to leap over the insulated section and cause dangerous discharge at the metallic termini. The parasitic earth currents arise from the difference in potential—in some cases amounting to 20 volts—between the tram rails and adjacent pipes, and these can best be minimized by lowering this potential. It is desirable, therefore, to increase the conductivity of the rails. Short circuits by lightning discharges can be obviated by more carefully arranged installations.

U. S. Geological Survey at the Panama-Pacific.—The central feature of the United States Geological Survey's exhibit at the Panama-Pacific Exposition, in San Francisco, will be two stagelike settings—partly model and partly painted—representing a district in the arid West both before and after development. In the before-development scene topographic engineers are at work with their instruments on the headlands, geologists have stripped a bed of coal and are taking samples for analysis, and other geologists are studying rock formations. In the foreground is an automatic river gauge; farther back a hydrographer is measuring the flow of the stream as it races by. In the background is a camp and pack train.

The second scene shows the same district after development. The results of the stream gauging have been utilized in planning a power plant that shows in the distance and an irrigation project that covers the valley floor. The coal bed is being mined, an oil field with derricks is under development, a sandstone bed is being quarried, and mining and milling are in progress in the mountains. A town has also sprung up and roads, railroads, and other evidences of civilization abound.

The scenes are illustrative of the basic work of the Geological Survey and also explain why this organization is not even better known than it is. It carries on the pioneer work and prepares the way for the engineer and the constructor; but when these men appear on the ground to erect permanent monuments to their professions, the Survey disappears from the scene and moves on to new fields.

Gas Lighting and Hygiene. M. VON GRÜBER. (*J. Gasbeleucht,* lvii, 690.)—Tests were carried out in rooms in which the conditions could be controlled. Sulphur dioxide and carbon monoxide could not be detected in the air in the rooms, even after the burners had been alight for 67 hours; traces of nitric oxide were usually present, the largest amount found being 10.4 c.c. per cubic metre. The quantity of carbon dioxide never exceeded 4 parts per 1000, and the temperature of the rooms was raised only a few degrees. In comparative experiments with gas and electric lights, the difference in the increase of the temperatures of the rooms amounted to 1.6° C., while the difference in moisture content of the air was generally less than 5 per cent. In the room lighted with electric lamps the ventilation was such that about one-third of the air was replaced per hour; in the room having gas lamps two-thirds of the air was replaced per hour. The hot gases from the lamps did not appear to have any disinfecting effect on the air.

Electrical Removal of Tar from Gas. F. W. STEERE. (*J. Gas Lighting*, cxxviii, 309.)—When crude coal gas or producer gas is submitted to an alternating high-tension discharge at 40,000 to 80,000 volts in an ionizer, the tar fog condenses to large globules, which can readily be removed by a centrifugal or by a Pelouze and Audouin extractor. In an experimental apparatus treating 30,000 cubic feet of gas per hour rich coal gas given off during the earlier part of the coking period was passed through a washer-cooler and then through the ionizer. The best temperature was 65° to 80° C. (149° to 176° F.). The naphthalene was separated in crystalline form by passing the tar-free, warm gases from the tar extractor through a washer-cooler, and the cooled gas contained only sufficient naphthalene vapor for saturation at the temperature of the gas. The separated tar contained little benzene and toluene, a larger proportion of these constituents remaining in the gas and increasing its illuminating power. This effect was increased by raising the temperature at which the gas entered the ionizer. The process has been used continuously since January, 1914, for removing tar from producer gas for use in engines.

Radium, Uranium, and Vanadium.—The year 1914 was an eventful one in the industry of mining radium, uranium, and vanadium ores and had by far the largest year's production yet made. Figures collected by Frank L. Hess, of the United States Geological Survey, indicate that the output amounted to about 4300 short tons of dry ore carrying 87 tons of uranium oxide and 22.4 grammes of metallic radium. The ore was valued at about $445,000. The ore produced in 1913 contained 41 tons of uranium oxide and 10.5 grammes of radium, and that produced in 1912 contained 26 tons of uranium oxide and 6.7 grammes of radium. About nine-tenths of the contained radium is thought to be recoverable under improved processes.

Although carnotite, a mineral of these rare metals, contains three times as much uranium oxide as vanadium oxide, the Colorado and Utah ores of these metals generally contain other vanadium minerals in such quantity that vanadium oxide is present in excess of the uranium oxide. However, little is paid for the vanadium, as its separation from uranium is troublesome, and only a few thousand dollars was received in 1914 by brokers or producers for the vanadium in the ores sold. Sandstone impregnated with roscoelite, a vanadium-bearing mica, is mined at Vanadium, San Miguel County, Colo., on the eastern edge of the carnotite field, by the Primos Chemical Company. The total quantity of vanadium in the carnotite and other ores mined during the year was apparently about 432 tons.

About the beginning of 1914, owing to the very high prices charged for radium salts, their scarcity, their evident usefulness in treating cancer and other hitherto incurable diseases, the practical impossibility of the poor receiving treatment by radium because of its scarcity and high cost, and to the fact that much of the radium-bearing ore was being shipped out of the country, Secretary of the Interior Lane caused to be introduced in Congress bills reserving radium-bearing lands from entry as mining claims, and providing for government purchase. The bills are still pending.

During the year the National Radium Institute conducted, under the supervision of the Bureau of Mines, mining operations at Long Park, near Paradox Valley, in Montrose County, Colo., and a plant at Denver for the production of radium and investigation of processes. The work has been so encouraging that Director Holmes has announced the probable production of radium at one-third of its present cost. Messrs. Lind and Whittemore, of the Bureau of Mines, state that their investigations show that carnotite carries proportionally to its content of uranium as much radium as pitchblende or other uranium minerals; that is, the radium has reached its maximum ratio to the uranium from which it is derived and is thus in equilibrium. From published results of experiments made on casual specimens of carnotite it had been popularly supposed that carnotite was less rich than pitchblende in radium.

In Utah the Standard Chemical Company made the first commercial production of carnotite ores from the Henry Mountains during the year, and the commercial production of uvanite, a radium-bearing mineral new to science, accompanied by other uranium minerals, one or more of which are yet to be described, was begun at Temple Rock, 45 miles southwest of Green River. Shipments were made from newly-opened carnotite deposits at Court House, northwest of Moab, Utah, and from deposits 16 or 18 miles southeast of Moab. A first shipment was also made from Blue Mountain, Routt County, Colo.

The Paradox Valley region was, however, as usual, the chief producing area, and from it came the bulk of the ores. The Standard Chemical Company was the largest single producer and shipped more than half of the country's output.

Two companies, the Standard Chemical Company and the Radium Company of America, produced radium salts during the year, and Dr. W. A. Schlesinger started a radium-refining laboratory. The opening of the European war stopped nearly all operations in both mines and reduction plants, for the two companies mentioned sold their product largely in Europe and practically all the ore bought by brokers was sold abroad. A little more than 1200 tons of ore, containing 28.1 tons of uranium oxide and 7.2 grammes of radium, was consigned to Europe, but, as the foreign refineries were closed, a part of it was held in transit.

No vanadinite or similar ores are known to have been sold for vanadium during the year, but a number of mines in New Mexico and Arizona shipped and sold such ores for their lead and silver contents.

Iron-titanium Alloys. J. LAMORT. (*Ferrum,* xi, 225.)—The equilibrium diagram of these alloys has been studied by the methods of thermal analysis. Alloys containing up to 24 per cent. Ti were prepared by melting ferro-titanium with mild steel in a kryptol furnace. The liquidus consists of two branches meeting in a eutectic point at 1300° C. and a composition of about 13 per cent. Ti. Iron retains about 6 per cent. Ti in solid solution. Microscopic analysis confirms the results of the thermal study, and also indicates the existence of a compound Fe_3Ti. Study of the magnetic properties showed that the temperature of the magnetic change is lowered by the addition of Ti. The curve showing the relationship between temperature of magnetic change and the Ti content is practically a straight line running from 0 per cent. Ti and about 787° C. to 21 per cent. Ti and 690° C. The presence of nitride and cyanonitride can be recognized readily under the microscope. The effect of additions of titanium to iron and steel most likely depends on whether the Ti exists in the alloy in the metallic state or in the form of nitride. This probably accounts for the variations in the results obtained by different workers in this field.

Locomotive Head Lamps. J. L. MINICK. (*Electr. World,* lxiv, No. 14, 656.)—The chief function of a locomotive head lamp is to warn persons on the track ahead that a train is approaching. A lamp having a centre-beam intensity of 500 candle-power can be seen 25 miles away by a person of average height, therefore it will give 25 minutes' warning of the approach of a train running at 60 miles an hour (on a straight track, with nothing to obscure the light! [abstractor]). To prevent blinding persons looking towards the lamp, the intensity of the light should not be higher than 15 or 20 candle-power per square inch of projected area. A 3000-candle-power lamp with a 16-inch reflector will have an intrinsic brilliancy within the maximum value. Second in importance among the functions of a head lamp is its ability to illuminate whistle posts, landmarks, etc., properly. These need not be illuminated with an intensity higher than 0.10 foot candle. This intensity will be produced by the side rays from a 500-candle-power lamp when the marker is about 50 feet ahead of the locomotive. No commercially available lamp will enable an engineer to see a dark object ahead in time to stop his train, as a dark dummy can be seen at night only 500 feet away when illuminated by an incandescent head lamp of 10,000 candle-power, and a train containing 12 standard steel coaches running 60 miles an hour cannot be stopped inside of 1660 feet with the most modern air-brake rigging, or 1235 feet with the electro-pneumatic system now being developed. Attention is also called to the fact that an intense head lamp will hinder flagmen and passing engineers seeing the train classification markers, and may even blot out or alter the color of semaphore signal lamps, etc. Valuable references on tests of and regulations on head lamp intensity were included in the paper.

Felspar Supply of the United States. A. S. WATTS. (*Trans. Amer. Ceram. Soc.*, xvi, 80.)—The demand for pure felspar being greater than European sources can supply, the author recounts the location and extent of felspar deposits (apparently pegmatite) in the United States east of the Mississippi River. The influence of the methods of mining and grinding upon the quality of the finished product is shown by the good reputation of Maine felspars, which are not naturally very pure on account of a quartz content which cannot be eliminated. Analyses given of American spars show variations in alkali content from 8 to 16 per cent. The chief States concerned are Maine, Connecticut, New York, and Pennsylvania. In the last-named the largest deposit of soda felspar in the world was found, but is almost exhausted. Maryland is expected to supply soda felspar in the future; the soda pegmatites contain 6 per cent. Na_2O and 4 per cent. K_2O. In Virginia and North Carolina felspar has been subsidiary to mica mining hitherto. In Georgia the production of felspar has not yet been attempted.

Coal Consumption of New York's Generating Stations. ANON. (*Electr. World*, lxiv, No. 14, 660.)—The average consumption of fuel in all the central stations of New York City is at the rate of 3.3 pounds per kilowatt-hour, inclusive of all standby and other losses. The average consumption of fuel by insolated plants is at the rate of not less than 10 pounds of coal per kilowatt-hour, or three times the average rate of central-station operation, according to a committee of the Association of Edison Illuminating Companies. Compared with insolated plants, central-station generation of electricity is conserving in New York City alone about 1,750,000 tons of fuel a year by superior economy in production.

Measurement of Air Velocities, Pressures and Volumes. W. CRAMP. (*Manchester Lit. and Phil. Soc. Mem.*, lviii, 7, 1.)—For various reasons the anemometer is unsatisfactory in measuring air velocities; it is rather an indicator. The Pitot tube is accurate, provided the facing tube is small and of such a form that stream-line flow is not much disturbed. Various tubes are compared; the Nipher collector is very inaccurate, and the Brabée tube seems superior to anything but the Standard Pitot with static tube in pipe wall. This latter involves holes with good internal surfaces to be drilled at various points, and is often impossible in commercial work. The Brabée tube seems very little affected by faulty setting. In determining the volume of air passing through a pipe, the author takes the central velocity x as a coefficient to give the mean velocity. For central velocities of 6.89, 7.72, 8.53, 9.16, and 9.42 metres per second, the coefficient is 0.8, 0.9, 0.9, 0.9, and 0.88 respectively. With water flow the author remarks that the coefficient is about 0.85. The Krell-Prandtl pneumometer is also described.

Peroxidized Kerosene as Motor Fuel. G. B. SELDEN. (*Petroleum,* ix, 1304.)—Kerosene and other heavy petroleum oils can be utilized as fuel for internal-combustion engines if small quantities of peroxides or other highly-oxygenated substances, such as picric acid or nitronaphthalenes, etc., are either dissolved in them or sprayed into the air inlet of the carburetter. Thus petroleum with 3 per cent. of hydrogen peroxide is stated to be perfectly stable, to differ from the original oil but little in either color, specific gravity, or flash-point, and to burn perfectly clean and without residue in the cylinder or odor in the exhaust. The power of the engine is, moreover, increased. Although aqueous peroxide may be used as a spray, it is preferable to shake the aqueous peroxide with the oil, and allow to separate. The hydrocarbon layer will then contain most of the hydrogen peroxide, and is decanted off. Many nitrated substances have been also employed in amounts varying from 0.5 to 5 per cent. in solution in the oil with similar results. It is claimed, for example, that an addition of 2 per cent. of naphthalene picrate increased the power of the engine by more than 100 per cent. Similar nitrated compounds of naphthalene, phenanthrene, pyrene, and picene have also been used.

Applications of the Coolidge Röntgen-ray Tube. W. P. DAVEY. (*Gen. Electr. Rev.,* xvii, 792.)—The main advantages in the use of the Coolidge tube are: (1) The independence of the quantity and the penetrating ability of the rays produced, (2) the ease and rapidity with which the quantity and penetration of the rays may be regulated, and (3) the fact that when the tube is once adjusted to the requirements of the operator it needs no further attention. To bring the tube to any desired adjustment, the operator pulls a handle which regulates the current through the tube, thus determining definitely the quantity of Röntgen rays produced. He then adjusts the voltage across the tube until the penetration is of the desired degree. The radiographs reproduced show what a wide range of work can be done with a single Coolidge tube, and they suggest that this tube is destined to become a precision-instrument of value to the botanist, biologist, and mineralogist, as well as to the physicist and the physician.

PRESS OF
J. B. LIPPINCOTT COMPANY
PHILADELPHIA

JOURNAL
OF
THE FRANKLIN INSTITUTE
DEVOTED TO SCIENCE AND THE MECHANIC ARTS

VOL. CLXXIX APRIL, 1915 No. 4

AN AMERICAN ENGINEER IN CHINA.*

BY
WILLIAM BARCLAY PARSONS, C.E., LL.D.,
Consulting Engineer, New York, N. Y.

LAST spring, when The Franklin Institute extended to me its very complimentary invitation to deliver a lecture to the title of "An American Engineer in China," it appeared as if industrial development in that country would continue to progress or remain stationary, just as it had been doing for some years in the past, regulated largely by the intrigue of European politics, and in which the American engineer was destined to play but a small part. At that time the possibility of a war which would embroil all of the European powers which had interests in China was scarcely within the realm of probability. Although at this time it is not possible to set limits to the effects that will follow this war, nevertheless there can be no doubt but that the effects will be so far reaching as to include China and Chinese enterprises, and it is not impossible that the position of an American engineer in China may be greatly altered, and, if so, it can be altered only to his benefit. The moment seems, therefore, opportune to briefly review the present condition of China's engineering development, including a review of her mineral wealth, and recall the factors that have influenced such development. The great world-change that is bound to come will surely cause the future development to follow new lines, under a greatly-altered combination of in-

---

* Presented at the stated meeting of the Institute held Wednesday, December 16, 1914.

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

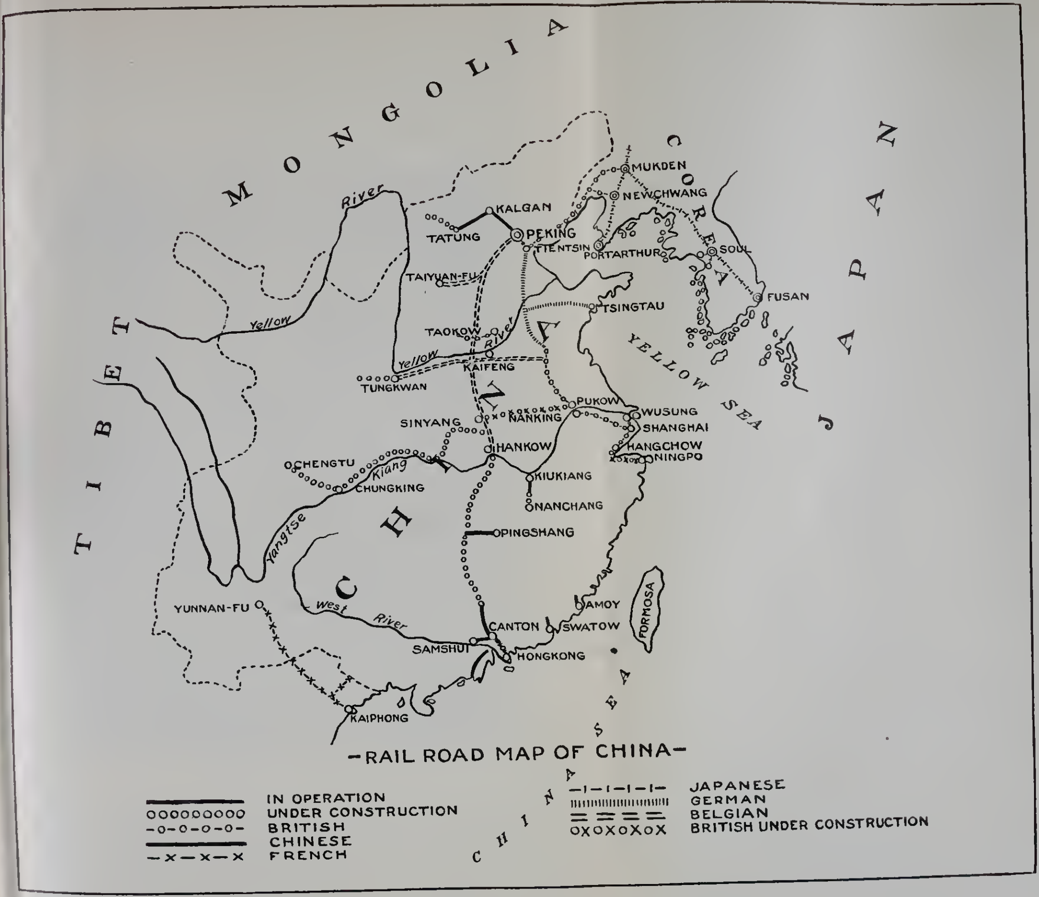
Copyright, 1915, by THE FRANKLIN INSTITUTE.

fluences and with results that no man can now foresee. All that we know is that we are at the point of departure for a new course whose bearings are now undetermined.

Whenever China or things Chinese are considered there is always a great opportunity for a diversity of views, leading at times to direct contradictions between even accurate observers, owing to difference in viewpoint. Chinese character and Chinese customs are always open to misunderstanding, due, perhaps, to the fact that they are so frequently just the opposite from what we do or would do under like conditions, and to the further fact that the several parts of the country differ radically between themselves in local customs, architecture, and mode of living, and perhaps largely to the lack of intercommunication in spoken speech. Thus we frequently see two authors, both claiming to be writing accurately of China but presenting distinctly different aspects. It is because each forgets that the particular part of the country with which he is familiar does not necessarily find a counterpart elsewhere and should not be taken as an example of Chinese life as a whole.

This uncertainty in regard to China and its interesting people and problems begins with the name of the country. "China," which is a foreign and not a native term, may cover two quite different territories. It may be applied to what is generally described as China "proper," or the country of the eighteen provinces, or it may include with that area the outlying dependencies of Manchuria, Mongolia, and Tibet, over which the Peking government has exercised a more or less tenuous rule, which, however, has been growing steadily less effective, especially during the past few years, when Russia and Japan have been actually taking territory under their direct control or have been undermining the Chinese power, or, as the people themselves, asserting independence, have refused to acknowledge any longer the suzerainty of Peking.

For the purpose of this address, China will mean China "proper," as extending from the Mongolian line, about latitude 44 degrees, to the China Sea, about latitude 20 degrees, and from the eastern seaboard to Tibet, covering an area of 1,432,795 square miles. A comparison of this figure with 2,970,038 square miles of the United States, exclusive of lakes, and with 1,931,249 square miles of Russia in Europe, will give a mental picture of the



-RAIL ROAD MAP OF CHINA-relative size of the country. With its dependencies, the area of the whole Empire is about 4,300,000 square miles, or about one-fifth larger than the whole of Europe.

China reaches north and south from the latitude of northern New York to that of Cuba, and furnishes corresponding ranges of temperature, but, as the summers in central and southern China are wet and humid, the hot weather is much more enervating than that in similar latitudes in the United States.

A Chinese city street.

Topographically, China is divided into three basins, or watersheds, formed by the three main rivers flowing in parallel lines from west to east. Of these, the largest is the Yangtze Kiang in the centre—a truly noble stream rising in Western Tibet and traversing some 3100 miles before it reaches the sea. North of the Yangtze is the Hoang Ho—2700 miles long—otherwise known as the Yellow River, and frequently called by the natives "China's Sorrow," on account of the great damage it has done and still does in periods of flood, and also by its erratic behavior in bodily moving its bed from time to time over a distance north and south of 600 miles. South of the Yangtze is the Si Kiang, or West River, with a length of 1250 miles. The existence and location of these rivers are important to keep in mind, as they have determined the main routes of trade in the past and will necessarily greatly influence the routes in the future. The last two are navigable for long distances. Large steamboats ascend the Yangtze to Ichang, about 1000 miles from the sea, where the gorges and rapids prohibit, for the present at least, further progress, except for one small launch which braves the rapids as far as Chungking. During the summer, when the Yangtze is in flood, ocean-going steamers ascend as far as Hankow (600 miles) for cargoes of tea, a minimum depth of from 40 to 50 feet being available for the whole distance.

Of the population of China much has been written and many myths have come to be believed. It has always been the popular idea that China contains a population so vast and so congested that the struggle for existence is intense. The struggle is intense, but this is due not to overpopulation but to lack of profitable diversity of labor and of transportation facilities. We used to be taught that Peking and Canton were more populous than London. The number of people in China has been stated by some authorities to be at least 500,000,000. No real census has ever been taken, nor is one possible with the lax and unscientific methods of Chinese government. Some few years ago the speaker hazarded a guess, based on his own observations in part and partly on statements of others of like opinion, that the population of China did not exceed 200,000,000. At that time the official estimate was nearly 400,000,000. A recent count of families seems to indicate a population of 310,000,000, the smallest official figure ventured in many years, but there is a doubt even in China but that this is an over- rather than an underestimate. The reasons for the error in overstating are many: First, the Chinaman himself is fond of dealing in large figures. He uses the expression "ten thousand" precisely as the ancient Greeks used the same figure of speech "murioi," or ten thousand, not to denote an exact figure, but a large quantity. So the Chinaman speaks of ten thousand or many tens of thousands to indicate a great or very great number, and, curiously enough, seems to have the impression of being very accurate in so doing. The second reason is that the streets of a Chinese city—Peking excepted—are exceedingly narrow, so that comparatively few people produce a great congestion and give the impression of an immense overcrowding. Third, the Chinese live in villages and cities, and it is with these, more than the open country, that the foreigner is familiar and which, with their overcrowded streets, have led him to accept the loose and inaccurate Chinese statistics. In the country one may travel for miles and at times see but few houses, as the people do not, as a rule, live on their farms, but have been accustomed to herd in villages, chiefly for reasons of mutual protection against robber bands, and in some few districts on account of communal holding of land.

A Chinese farm-house.

The birth-rate is undoubtedly high, but proportionately high, or perhaps relatively higher, is the rate of mortality, especially among children, and this high death-rate has kept down an excessive increase in population.

Inaccuracy, or perhaps one should say entire failure to appreciate the necessity for, or even the existence of, accuracy, is met at every turn in China. Thus the monetary unit, the tael, has no physical existence as a coin, being nothing more than a weight in silver, and its value is almost as indefinite as its form, there being more than 60 taels recognized throughout the country, differing quite distinctly in value. So it is with the Chinese system of weights and measures. The Chinese foot, the basis of measurement, varies from 8.6 to 27.8 inches, and there are over 100 different kinds of feet in use in China. Apart from the length of the foot varying locally as the tael does in value, each trade has its own standard foot; that is, the carpenter, the mason, the tailor, and the junk builder each has his own foot. The mow, which is the unit of superficial measurement of land, and which in Shanghai is taken at about one-sixth of an English acre, as a matter of fact varies according to locality from 3840 square feet to 9964 square feet. In going through the country it is quite impossible to ascertain distances. As coolies are paid by the li (one-third of a mile) for portage, wholly arbitrary and fictitious scales of distances between villages have been adopted, always in excess of the actual figures, but which the native will not see, or at least admit, are not accurate.

The all-important need of China is greatly-improved means of transportation, not only for its industrial and economic development, but for the amelioration of the condition of its people. To Americans, with more than 250,000 miles of railways in their own country, it is difficult to imagine another country with one-half the area of theirs and twice and a half its population, with fewer miles of railway than there are in the comparatively small State of Tennessee, and without a single highway worthy of the name.

In Northern China, where the horse and cart, and in some districts the camel, are used as means of conveyance, there are a few highways, for the most part leading to Peking, once, perhaps, in fine condition, but now sadly in need of repair. As one goes south the cart disappears, the horse and small pony, bred in Mongolia and Manchuria, become scarcer, and the highway dwindles into a footpath only, over which goods are carried on men's backs, or rather on their shoulders, suspended from a bamboo yoke, or on wheelbarrows. Under such conditions traffic, except along the rivers, exists only where it can afford to meet the excessive cost that necessarily is self-imposed. The great, bulky commodities do not move at all. Whole districts are cut off from any benefits arising from contact with the outer world or other parts of China, and are reduced to self-supply and self-support. If there is a shortage of crops there is a famine; if a surplus, a waste. As there is a lack of diversity of labor, wages are reduced to the minimum figure of barest support of life, and the condition of the people in the interior is in some districts deplorable.

The carts and ponies of North China.

In the past the only outlets of traffic have been China's rivers, reinforced, where possible, by canals, of which latter it is estimated there are 20,000 miles open for boat traffic. As a consequence the Chinese boatman constitutes a large and important class. Many of them know no other home than their boats, on which, in fact and not rhetorically, they are, born, live, and die. At the treaty ports their junks will be seen lying many deep for long distances along the shore front waiting for cargo or charter. The women on board, in addition to household duties, frequently take their turn at oar or tiller.

On the lower reaches of the main streams, such as the Yangtze or West, there are large sea-going junks. As the rivers grow smaller and the depths less, the junks gradually are reduced in size to correspond with the decreased facilities, until they become "sampans," or, literally, "three boards," small flat-bottomed boats. The junks go under sail when the wind is fair, and when it is not they lower their large sail, for usually there is but one, and are towed by the crew walking on the river bank and hauling on a towing rope, sometimes made of bamboo fibre, leading from the masthead. When rapids, such as on the upper Yangtze, are reached, boats will collect at the foot of the rapids until there are enough men in the combined crews to haul the junks one by one upstream. By these boats are carried seaward, or to the treaty ports, the interior products, such as coal, rice, tea, etc., and as return cargoes imported manufactured goods.

In order to get these materials to or from the river the small highways act as feeders, on which the conveyances are pony, coolie, or wheelbarrow. A Chinese wheelbarrow is a much more sensible device than its Occidental namesake. Instead of the small wheel being at one end, so that the weight rests partly on it and partly on the man pushing it, the Chinese barrow has a large wheel in the middle, the load being balanced over it on both sides, somewhat in the nature of an Irish jaunting car. The wheel, therefore, bears the whole load, and its large diameter reduces friction. In some districts, to facilitate the wheelbarrow traffic, the highways are paved with long slabs of stone, in which the wheels have worn deep grooves.

Occasionally the demand for food supply is so great that all space is occupied by the rice fields, and sufficient area even for a wheelbarrow path is refused. The necessity for local supply transcends the demands for transportation facilities, owing to the people's ignorance of the latter's value, and the only highways are the winding tops of the dykes making the rice fields, on which coolies walk carrying their burdens. Along the highways inns or resting places for the men are found at frequent intervals, the path usually leading through the buildings. On the busier routes these inns will be found crowded with coolies.

Between Central China, the valley of the Yangtze, and Northern China there has always been a demand for means of communication, not only for local reasons but to reach Peking, the capital.

Coolie carrying merchandise on a highway in Central China.

These requirements have been supplied partly by highways, but more especially by the Grand Canal running into the Yangtze opposite to Chingkiang. Between the Yangtze valley and Southern China, the necessity for communication being less urgent, the means have been less well supplied than in the north, and there are but few roads across the dividing mountains. The most important was the route over the Cheling pass, connecting by a portage of 40 miles the headwaters of the Hsiang River, the principal tributary to the Yangtze from the south, with the headwaters of the Pei Ho, or North River, leading to Canton. In previous times this was the great trade route by which the tea and other products of Central China were carried to Canton, thence to be exported or distributed to other ports of China. This highway, explored by the speaker, had been paved and was lined for a great part of its length, not only with inns but with shops, so resembling a city street. At the heyday of its activity it must have presented a busy scene, but to-day the pavement is in bad repair, and the buildings are deserted. The introduction of steam on the Yangtze, opening it to commerce in 1861, has gradually diverted trade to that river and to export from Shanghai rather than from Canton, so that the glory of the Cheling route has passed away, to be restored, however, some day when the railway from Canton north is completed, reference to which will be made later.

A realization of China's need of improvement in interior transit was brought home to its people by the disastrous result of the Japanese war in 1894. At that time China had but one railway from Tientsin northeasterly to the Great Wall. It is true that a small line had been built from Shanghai to Wu-sung in 1876. It was taken over, however, by the Chinese in the following year on payment to its promoters of the cost of its construction, and then destroyed. In 1880 Mr. C. W. Kinder, an English engineer, built for the company owning the Kaiping coal mines a tramway about 10 miles long from the mines at Tongshan to tidewater. In order to operate this line more economically than by horses, Mr. Kinder built a small locomotive out of parts of other machines and which he appropriately named "the Rocket of China." At first the Chinese were much opposed to this revolutionary innovation, and great patience and operation of the locomotive, first within the terminal yard and then in short stretches at a time on the open line, were necessary in order to overcome the native hostility. Through the aid of British capital the line was extended to Tientsin by 1887, and by 1894 had reached Shanhaikwan, where the Great Wall ends at the sea.

At the conclusion of the war, when the Chinese government officials finally realized and reluctantly admitted that railways were a necessity, a number of projects were at once started. The British interests which were behind the Tientsin-Kaiping mining railway secured the privilege of extending it from Tientsin to Peking, and in 1897 gave through service from Peking to the Great Wall, a distance of 294 miles, and had begun construction beyond the Wall toward Manchuria.

In these earlier negotiations America took part, being represented in the movement by the late Senator Washburn, of Minnesota, and a small group in New York, under the lead of the late Clarence Cary. They secured a promise of a concession of the line from Peking to Hankow, which was considered to be one of the most important links to be constructed, as connecting the capital of the country not only with the chief city in Central China but with steam navigation on the Yangtze. The late W. W. Rich, formerly chief engineer of the Minneapolis, St. Paul and Sault Ste. Marie Railway, made a survey of the route in 1896.

Junks on the Yangtze.

A glance at the map indicates the political and strategic importance of this line, and influence was at once brought to bear by every foreign power for its possession.

China at that time was hopelessly weak. Russia, having deprived Japan of its fruits of victory by taking possession of Port Arthur, had obtained from China the right to construct railways in Manchuria and to guard them, which authority afterwards developed into the maintenance of a large army in Manchuria. England, as an offset, had taken the port of Weihaiwei, and Germany, availing itself of the murder of some missionaries in 1897, obtained a "lease" of Kiaochau as compensation, while France and even Italy were desirous of acquiring territory to obtain a foothold, all believing that the long-expected "breakup" was about to take place. It soon became evident that this rivalry might lead to a serious clash, to avoid which the competing nations agreed to establish among themselves the so-called "Spheres of Influence," whereby they recognized, in certain defined areas, predominating commercial and political rights. Thus, to Great Britain was conceded the Yangtze valley, to France the territory in Southwestern China adjoining its own possessions in Tongking, and to Russia the northern section next to Manchuria and extending southerly to Shangtung, which the Germans claimed as the hinterland to Kiaochau.

To permit an important railway line extending from Peking, the capital of the country and on which Russia had already laid envious eyes, to Hankow to pass into the hands of another nation was not to the liking of the European powers, and their influence was at once cast against granting this concession to the American syndicate. Great Britain would have objected to its being given to a Russian syndicate as violating their own agreement on "Spheres of Influence"; France had no right to ask for it; Germany would have been opposed by Great Britain, so Russia, which at that time undoubtedly controlled the court officials in Peking, succeeded in having the concession awarded to a Belgian syndicate, on the grounds that Belgium was a small country and with no desire for territorial acquisition. After the concession had been secured and work was begun it developed that, although Belgians were in nominal control, they had as partners, French banks, and through them Russians, so that Russia, through its allies in France, had succeeded in obtaining what it desired and what it could not have procured directly; namely, a share in the control of this exceedingly important trunk line.

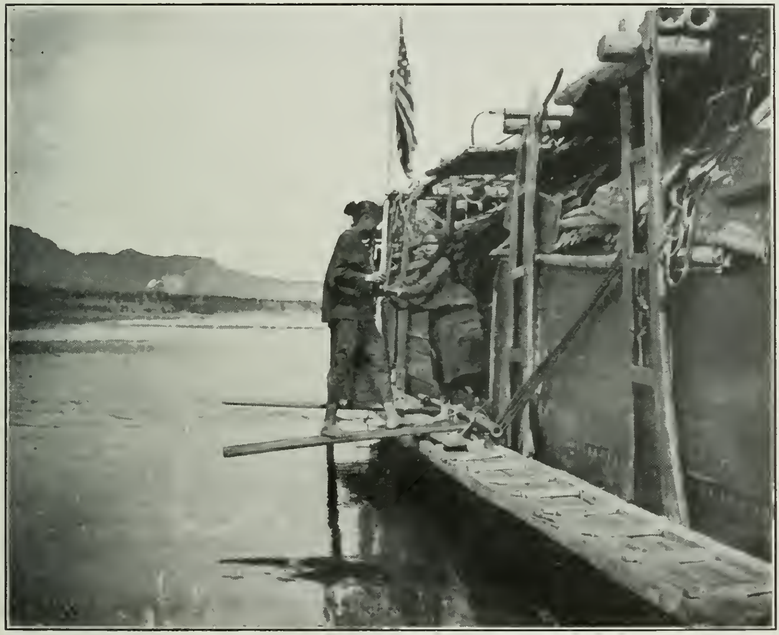
In the meanwhile, Senator Washburn had withdrawn entirely from the enterprise, and the New York group, now under the leadership of the late Senator Calvin S. Brice, finally procured, in 1898, a concession from the Chinese government for a railway from Hankow to Canton, a virtual extension of the Peking-Hankow line, and which, with it, divided China into halves east and west as the Yangtze divided it into halves north and south.

Junks at a treaty port waiting charter.

The year 1898 is usually taken as the real commencement of Chinese railway development. It was the year in which the Peking-Tientsin line was put in full operation beyond the Wall, in which the Wusung line (eight miles long) was reconstructed, in which the construction of the Belgian Peking line was actually commenced, and in which the survey of the American line from Peking to Hankow by American engineers was begun.

In China there is no general railway law. Each railway has been constructed under a special concession or contract, executed with the Chinese government, and obtained after long and very tedious negotiations, during which the promoters have been supported by the minister of their own country and usually opposed by the ministers of all other countries. The first of these concessions was that granted to the Belgian syndicate and whose terms were substantially duplicated in the American concession for the line from Hankow to Canton. These two concessions stipulated that the title to the property to be created was vested in the Chinese, the Chinese government creating an organization, in the case of the American concession, called the Chinese Railway Company of which a government official, Sheng Kung-pao, a man of very great ability, was made Director General. The Chinese Railway Company, through the Chinese Minister at Washington (at that time, Wu Ting-Fang), made a contract with the American China Development Company to provide a loan for the construction of the line, whose construction and equipment were to be supervised by the American company. To repay the cost of the work there were to be issued sufficient Imperial Chinese gold bonds, which bonds were secured by a first mortgage upon the property to be constructed and then the interest and principal, being government obligations, were guaranteed by the Imperial government in the event of the railway not providing sufficient net revenue to meet the service of the loan. These bonds bore five per cent. interest and were to be taken by the American company at 90, the company retaining as profit whatever difference in price above 90 that they could secure in their sale. In addition to this, the American company was to receive as further compensation a commission of five per cent. upon the entire cost of construction, except land and earth works, and for a period of 43 years 20 per cent. of the net profits of the railway. This participation in the enterprise was to be represented by giving to the company debentures or shares to an amount equal to 20 per cent. of the cost of the railway, the remaining 80 per cent. to be retained by the Chinese Railway Company, the latter having the right at any time within the period of 43 years to redeem the American debentures, so-called, at par. The general principles as outlined above form the basis for most of the succeeding concessions.

The latest concession was for the Pukow-Sinyang Railway, executed in 1913, to a British syndicate, and provides for a definite bankers' commission of 5½ points on the actual selling price of the bonds, and in addition a purchasing commission of five per cent. upon all materials purchased for the line. The funds resulting from the sale of the bonds are to be deposited with a British bank—in this particular case the Hong Kong and Shanghai Banking Corporation. In lieu of the 20 per cent. division of net earnings, which first appeared in the Belgian and American concessions, and was subsequently repeated in the Shanghai-Nanking Railway (a British) concession, a payment of £120,000 was to be made, and then the whole of the net receipts of the line were to be retained by the Chinese government. The concession further stipulated that the engineer, the manager, and the chief accountant are to be British nominees.



Woman at the oar.

Under such conditions the amount of profit in carrying out a Chinese railway concession would seem to be relatively small to the size and importance of the undertaking, and the question might be asked why it should be undertaken at all, as it would appear that capital could be very much better employed in any one of the British colonies, for instance, or even in the United States, at a very much higher remuneration than 5½ per cent. bankers' commission and 5 per cent. purchasing commission on materials alone. Thus it would certainly appear to an American syndicate. But herein lies the first difference between European and American participation and one of the reasons why American syndicates have not taken as active an interest as those of European countries. For many years past all European nations have been seeking the acquisition of land abroad, into which to divert unemployed population or the excess products of their factories and commercial enterprises, and no European government has hesitated to support openly through official channels the efforts of the people of its country to expand commerce or to seize unoccupied fields, and have even entered into secret alliances with specially-favored groups. This has undoubtedly resulted in developing European trade and at the expense of the American trade where similar government support and alliance have been an impossibility.

As stated above, with the dismemberment of China following the Chinese-Japanese war looming not only possible but highly probable, it was the desire of every European government with oversea interests, in the event of such breakup, to obtain as much territory as possible, and in advance of it to secure the most advantageous position from which to press claims. Railways were obviously the very best opportunity for gaining such a foothold. Leading European powers, therefore, gave their financiers and large contractors not only official encouragement but instructions to secure every railway concession.

As to why the various syndicates were so keen to procure concessions which on the face of them were not very profitable, there were several reasons. One was, perhaps, patriotism, or at least a desire to advance national interest. On the financial side the profits, while on their face small, were nevertheless sure and actually much larger than they appeared to be. Bankers, took little risk and no responsibility. The securities to be issued for the cost of the work were the direct obligations of the government, and China has never yet failed to meet its foreign or domestic obligations as they became due. If the railways themselves were profitable, the syndicate received 20 per cent. of its net profits; if they were not profitable, the principal of the cost of the work and the interest were guaranteed by the government. Bankers, therefore, receive a quite liberal banker's commission for making an issue at a price to be determined by them at which the issue was certain to be taken by the public. Furthermore, after the bonds have been sold the bankers retain in their possession the funds thus received until they are finally expended in construction, or, say, for a period of two or three years, allowing in the interim a smaller rate of interest than the bonds themselves pay, which last is a capital charge against construction. The difference between the allowed rate and what the capital would earn was certain to be one or two points per annum. The bankers' profits are, therefore, real and are sufficient to attract bankers in ordinary times.

Chinese wheelbarrow.

The construction profits are not so immediately apparently generous. The syndicate is limited to a commission of five per cent., in some cases on materials purchased, in other cases on cost of construction, and, as required by the concessions, tenders for the supply of all material are to be invited and a decision rendered nominally by the Chinese Director General. Every one of these concessions, however, stipulates that the engineer, and in some cases the manager and accountant, shall be of the nationality of the syndicate to whom the concession is granted and to be named by them. This clause is the keystone of the structure. Although the furnishing of supplies is apparently open, in which manufacturers of railway material from any country will be allowed to compete freely, as a matter of fact the specifications can be, and usually are, so drawn as to limit the purchase of materials to certain selected concerns. A combination of bankers, contractors, and railway supply manufacturers, therefore, finds in a Chinese railway concession a very good opportunity to realize profits without risks. The bankers get their commission as stated above, the manufacturers are able to sell their materials at generous figures against very restricted competition, with assured payment, because the actual cash is in the hands of their own bankers, and then, after the railway is completed, to be able to continue to supply railway material on reorders because the management of the railway is in the hands of their own appointees. The five per cent. commission that the company is to receive on the purchase of materials becomes a small factor.

No long argument is needed to prove that such a system of developing the railway system of a great country is highly injurious to its best interests. The promotion has usually been not for the construction of the lines of the greatest local requirements, but those which would most strengthen the political aims of the government of the country of the promoters. From the time construction began and continuing on through the operation of the railway there is no incentive at any point for economy on the part of the promoters, who are the powers in control. Their profits are in proportion to purchases of materials and sales of bonds. The Chinese Director General may make a feeble protest, but it is a futile one to empty air, since there is no one to whom he can appeal. If he objects too strongly, political influence will be exercised for his "promotion" to some other office and his position filled by some one who will limit his activities to drawing his salary and securing appointments for needy relatives, of whom he always has many and who, according to Chinese custom, feel they have a right to demand support by their favored clansman.

It is a singular fact that any reform of the wasteful system would meet with strenuous opposition by the Chinese themselves. They consider it the very height of wisdom in statecraft to distribute concessions or favors among many nationalities, thinking that in some way they are playing one nation against another, and through many complications—and complications never seem to worry the Chinese mind—that they escape the danger of making any group or few groups too powerful. Moreover, they

Highway paved with slabs for wheelbarrows, which have worn a groove in the stones.

are very suspicious of foreign control. As will be shown later, they limit by law foreign participation in mining enterprises to 40 per cent. of the capital, and on the same principle there are no shares in and therefore no stock control of railway companies, thus preventing not only foreign ownership in the railways but even participation in their earnings, with the result that it is nobody's great concern to develop the earnings beyond the point of meeting the interest on the bonds and so avoid the project becoming a charge on the government. For the sake of China it is hoped that some day a more liberal policy will be adopted to result in a wiser method of projecting railways and a more economical one of construction.

Whatever will be the extent and force of European influence in China after the great realignment of the "powers" after the present war is ended, it is obvious that such influence will certainly spring from new political combinations and may be pressed much less energetically, as requirements at home for rehabilitation and repairs of the waste of war will probably deter capital from seeking such foreign investment, and that perhaps European nations for a while will not be so keen in the race to establish "Spheres of Influence." If so, there may arise America's opportunity. But, if the fruits of the opportunity are to be reaped, something more will be required than sending manufacturers' catalogues or even skilful salesmen with the expectation of cabling back profitable orders. China is a rich field. It is one, however, without capital and that has to be carefully developed. Our manufacturers will not and need not be parties to colonizing schemes nor the securing of territorial rights. They must, however, be prepared to establish and maintain a commercial organization at least the equal of similar heretofore existing organizations of other nations, and in that organization to keep in mind the importance of the engineer, who must possess diplomatic ability, commercial acumen, as well as scientific knowledge and experience.

The present railway development in China is shown on the map and consists chiefly of three trunk lines with certain branches: First, the Peking-Tientsin line, which is now extended to Mukden and to Newchwang, where it connects with the Manchurian system; second the Peking-Hankow line, and third, the line from Tientsin to Pukow, on the Yangtze, opposite Nanking, and from the last-named point to Shanghai, and southwesterly from Shanghai to Hangchow. The Peking-Tientsin-Mukden system, nominally a Chinese government line, is practically under British influence. The Peking-Hankow system, as explained above, is under Belgian-French-Russian influence, while the line from Tientsin through Pukow and Nanking to Shanghai is a combined German and British concession, the Germans taking the northerly half, including the branch to Tsingtau, and the British taking the southerly part. In southern China there is a line running from Yunnan-Fu southeasterly to connect with the French railway system in Tongking, and a small section of railway running west and north from Canton owned by the Chinese, being a portion of the lines covered by the original American concession, which was taken over by the Chinese through purchase in 1905, together with a line running southeasterly from Canton connecting with a British line in the British territory of Kowloon, opposite Hong Kong.

Highway on top of dykes between rice fields.

The railways existing in China at the present time, as given in "The China Year Book," are:

Railway	Influence	Date opening	Miles operated	Miles under construction
Wusung[1]	B.	1876	10	...
Peking-Mukden[2]	B.	1880	617	7
Peking-Hankow[3]	BL.	1889	816	...
Tayeh Iron Mine	C.	....	17	...
Pinghsiang[4]	C.	1902	65	...
Canton-Hankow	A.C.	1904	138	683
Shantung	G.	1904	310	...
Taokow-Chinghua	B.	1904	96	...
Swatow	C.	1906	30	...
Shansi	BL.	1907	151	40
Shanghai-Nanking[5]	B.	1908	200	...
Shanghai-Hangchow	B.	1908	118	...
Hangchow-Ningpo	B.	....	...	123
Hsuchow-Tungkwan	BL.	1908	400	...
Peking-Kalgan	C.	1909	202	130
Amoy	C.	1910	18	15
Kiangsi	C.	1910	35	52
Yunnan	F.	1910	289	...
Kowloon-Shumchun	B.	1910	23	...
Canton-Shumchun	C.	1911	89	...
Tientsin-Pukow[6]	B.	1910	237	...
Tientsin-Pukow	G.	....	460	...
Total			4321	1050

Meaning of letters: A.—American. B.—British. BL.—Belgian-French-Russian. C.—Chinese. F.—French. G.—German.

The dates of opening show how recent is even the small growth. The miles of railway stated as under construction are of lines, initial portions of which are already under operation, and the remaining under construction to some extent, but with no definite or, for the most part, possible near date for completion. The length of Chinese-owned railways, both within and without China "proper," is about 6300 miles. The above railways are all of standard gauge (4 feet 8½ inches), except the Yunnan and Shansi Railways, which are of metre gauge, and also a short line, 17 miles long, connecting the Tayeh iron mines with the Yangtze and used only for the hauling of ore.

---

[1] Taken up by Chinese in 1877, rebuilt and reopened in 1898; now part of Shanghai-Nanking Railway system.

[2] Tongshan colliery line in 1880, opened to Tientsin in 1887; extended to the Great Wall in 1894; to Peking in 1897, and to Mukden in 1903.

[3] Opened through to Peking in 1905.

[4] Built with Chinese capital, now part of Canton-Hankow Railway.

[5] With Wusung Railway, total mileage of system is 210 miles.

[6] Opened through Tientsin to Pukow in 1912.

There are many lines that are projected, for some of which concessions have been granted and officially executed, but, as Chinese affairs under the present system must be looked at through European spectacles, it is doubtful whether all the existing contracts will be carried out immediately, at least as now planned. The lines that are under survey and which are the most likely to be carried out in the near future are:

1. The completion of the original American concession from Canton to Hankow, 683 miles.

2. A line branching off from the Hankow-Peking line running westerly through Ichang, thence up the valley of the Yangtze through the gorges to Chungking, and thence on to Chengtu, about 800 miles; and another line easterly from Sinyang, on the Peking-Hankow Railway, to Pukow.

3. An extension of the British lines from Hangchow to Ningpo, on the coast, 123 miles.

4. The Shasi-Singyi Railway from Shasi, on the Yangtze, southwesterly to Singyi, in Kueichow, with branches about 800 miles. This is known as the concession of the Pauling Company, a firm of British contractors.

Of the Yangtze valley line the section from Ichang westerly to Kueichow, on the border line between the provinces of Hupeh and Szechuan, is known as the American section, a sufficient portion of the loan to complete this section having been taken by American banking houses. This section is now under survey by American engineers. The remainder of the line between Chengtu and the Hankow-Peking Railway is covered by French and German grants, respectively west and east of the American section.

In spite of the fact that two of the three great rivers of China are navigable for a large portion of their length, there is no doubt but what the river navigation should be supplemented by the railway communication, and that the same result will be found in China as in the United States, that railways can live and thrive on the banks of great rivers. The line that is now projected in the westerly portion of the Yangtze valley is along that portion where river navigation, except under the most extraordinary difficulties, is impossible. The Sinyang-Pukow concession is a virtual extension of this proposed railway to Pukow, whence, by ferry to Nanking, the Nanking-Shanghai Railway is reached, thus making, when completed, a through line paralleling the Yangtze from Western China to the sea. This is a highly important link in China's transportation system and will, if economically constructed, prove profitable. In the same way the line that runs from Canton to Samshui should be extended westerly along the valley of the West River, eventually as far as Yunnan-Fu.

Highway inn for coolies.

As proving the fact that railway communication can exist along the banks of rivers, the writer points out with pleasure the justification of a recommendation made by him in the construction of the Samshui line. This little piece of railway is some 30 miles long, running westerly from Canton through the manufacturing city of Fatshan to Samshui, and is paralleled the whole of this distance by water communication, a part of the very complete system of internal waterways leading in all directions from Canton. On these rivers there are found not only the ordinary Chinese junk but a very extraordinary development of the junk consisting of a mechanically propelled one with a stern wheel like a Mississippi River steamboat, operated by gangs of coolies on a treadmill. These boats will carry from one to two hundred passengers and at a speed of from five to six miles an hour. For those who desire privacy and rapid transit there is a small boat, called the "slipper" boat, according to its shape, in which the passenger reclines at length in the bow of the boat under a hood and the boat is propelled by three oarsmen. These means of communication seemed to have met all the requirements of the suburbs of Canton, especially where the distance to be travelled from Fatshan to Canton was not over 15 miles and where a railway labored under the disadvantage of having its terminus across the river, necessitating a ferry transfer to the city. The Chinese and many foreigners doubted that a railway would pay in this

Pei Ho. On this river the boats have double masts.

district, the lower toll for the river boats being considered as controlling the situation, especially in a country where a few minutes of time were not considered of enough value to save at the cost of real money. These 32 miles were constructed by the American company and now carry about 3,500,000 passengers annually—by far and away the heaviest passenger traffic of any railway in China.

China's mineral wealth is both varied and abundant, but, fortunately, coal is found in great quantities generally throughout the country; in fact, there is scarcely one of the eighteen provinces but that contains coal in paying quantities. Through lack of extensive railways and of power-consuming industries, except a few factories at Shanghai and other treaty ports, and on account of the great poverty of the people, consumption of coal per capita in China is very small. Nevertheless, something like 15,000,000 tons are produced annually from the Chinese mines.

Summit of Cheling Pass.

Coal is found in three varieties, lignite, bituminous and anthracite, with the intermediate grades of semi-bituminous and semi-anthracite. At present the greatest producing districts are the metropolitan province of Chili, where the Kaiping mines are the largest and best known, and Shansi. The former field is chiefly bituminous and the latter anthracite. Shantung, through German development of its mines, Hunan, and the province of Kiangsi are also good fields, with annual outputs of a million tons each. In Kiangsi there are located the Ping Hsiang mines, producing an excellent grade of coal, which is coked on the ground and transported now by railway to the Hsiang River, and thence by boat down the Hsiang and Yangtze to be used in China's sole blast furnaces at Hankow. These mines are Chinese owned.

Shops in large part abandoned along Cheling highway.

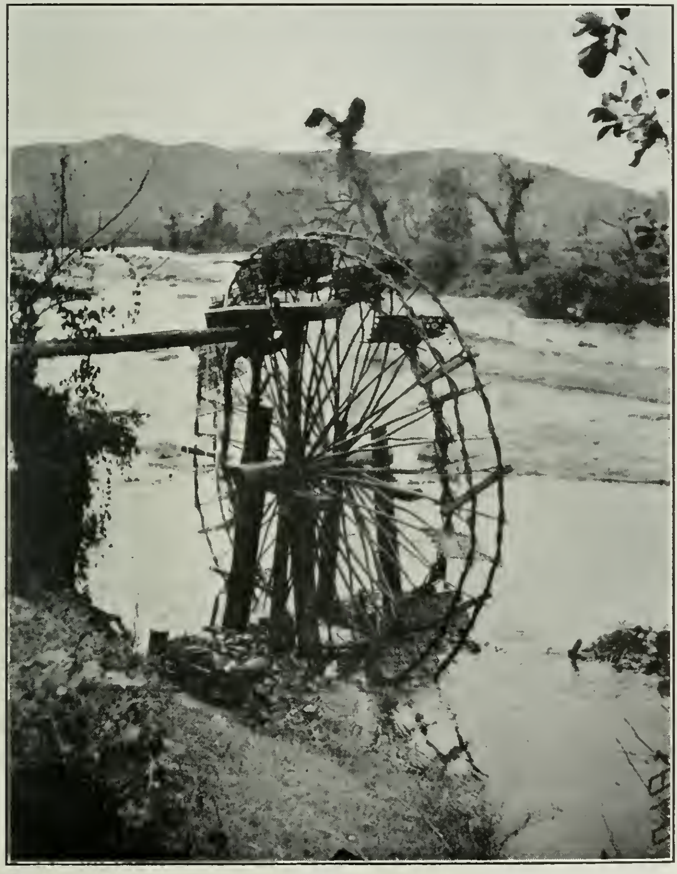
but developed by foreign engineers, and are equipped with thoroughly modern and efficient machinery.

The Chinese native mine is a very singular affair. The native attacks a vein at its outcrop and usually, for some unknown reason, at a point where the vein works down the seam. He drives simply a small tunnel not over five feet high and not over four feet wide, in order to avoid timbering, and carries this downward until he reaches a point where his native pump can no longer handle the inflow of water. When that point is reached the mine is considered as worked out and is abandoned. A Chinese coal mining district, therefore, presents a view on a larger scale somewhat like the mouths of the burrow pits of the western prairie dog, with a multitude of small waste piles dotting the hillsides. From this initial drift there are no side galleries and no rooms. On the floor of the drift are laid two longitudinal timbers, like rails. The coal is loaded into wicker baskets and then hauled up the drift on the rails by manual power. In the Hunan native mines inspected

Stern-wheeled junk, worked by men.

by the writer the only lighting system was that of joss sticks of punk, giving, of course, nothing but a very faint glow.

A great deal of Chinese coal is coking coal. Some of the anthracite is sufficiently hard and firm to stand the burden of a blast furnace, though nearly all is much softer than its American namesake, similarity existing in chemical composition. A great part of the bituminous coal, however, carries a large percentage of ash, and very much of it is in structure so friable as to produce but a small portion of lump. When the coal deposits can be worked on a large scale and generally throughout the



Undershot water wheel raising water for irrigation.

country, it will be found undoubtedly advantageous to crush most of the coal, wash it, and then either convert it into coke or to compress it into briquettes. The principle of briquetting has already been adopted by the natives, who take the coal dust, mix it with clay, and sell the clay balls in the Chinese cities for local consumption. By washing the coal from the Ping Hsiang mines, from which is made the coke for Hankow iron works, the ash content is reduced from as high as 28 per cent. to 8 per cent., and the sulphur from 0.65 per cent. to 0.1 per cent.

There has never been any approach to a complete scientific study of either coal or other mineral resources of China. About forty years ago von Richthofen made the first attempt to describe Chinese mineral wealth, and his publications, meagre as a first survey in such a huge country must necessarily be, are still referred to authoritatively. The Carnegie Institution of Washington sent, in 1903, a staff, consisting of Messrs. Willis, Blackwelder, and Sargent, who explored a portion of the country and described the geology which they saw. Other writers have also taken it up in part. Until the country has been thoroughly and systematically studied, it is impossible to say how great is China's wealth in coal. Enough, however, has been shown to indicate that China probably possesses at least as much coal as does the United States. Of other minerals China has her share. Iron ore, and of good grade, is found generally throughout the country, but in large quantities only in a few localities. Owing to the fact that up to date there has been but one blast furnace in existence, although others are under construction, the iron ore deposits have been developed on a large scale only at Tayeh, near Hankow, in proximity to the furnace. This ore shows, on analysis, metallic iron ranging from 60 per cent. to 62 per cent., with phosphorus and sulphur as low as 0.05 per cent. Copper is found generally throughout the western part of the country. Tin is found and worked to a considerable extent. Petroleum is found in the northern and western part of the country, and an arrangement has been recently entered into between the Standard Oil Company and the government for its development on a commercial basis. Lead, zinc, and antimony also occur; in fact, of the last metal the world's largest single producer is China. Gold and silver are also found, but up to date only in comparatively small quantities.

The system of developing mines in China is in somewhat better condition, speaking from a legal point of view, than the development of railways. The control of the mining deposits has been placed in charge of the Minister of Industry and Commerce, and a set of rules has been drawn up regulating the opening and working of mines, but, unfortunately, these rules are hedged in with so many Chinese restrictions that they do not attract capital on a large scale. It is instructive as showing the Chinese view of foreign participation, and also amusing, to read the opening paragraph of the mining regulations, to the effect: " The industrial enterprises of China are still in their infancy, and the inclination of the people to launch into industrial enterprises has not yet been developed; therefore, it is inevitable that foreign capital should be introduced, but as the nation has been so weak, it is feared that many interests and privileges will be lost. Consequently, in the question of development by foreign means there should be restrictions. Should there be foreign shares, they should not exceed forty per cent. of the total amount of the capital." The regulations themselves then proceed at length to describe the methods of working the mines, and those more interested in this phase of the question will find them set forth in full in " The China Year Book of 1914."

Although the regulations, on reading, appear to be fair, on a detailed examination by one with a knowledge of Chinese methods there will appear all sorts of opportunities for vexations and delays.

There is one iron works and steel mill, usually spoken of as being located at Hankow, but actually at Hanyang, on the opposite side of the river Han. This plant, though developed by Belgian engineers, belongs, it is believed, to Chinese capitalists, but subject, including the coal and iron mines, to a Japanese held mortgage of 13,000,000 yen. There are two furnaces of 100 tons each and one of 250 tons, and 5 Siemens-Martin open-hearth furnaces. The rolling mill has a capacity of 800 tons, and is used chiefly in making rails. Since China is a great consumer of small bars and the light shapes, rods, wire, nails, etc., it would seem as if a greater profit could be made in rolling such articles rather than rails. For the one there is always a demand, for the other only when railway construction is active. Moreover, rails should be manufactured to strict chemical and physical requirements, while for the articles mentioned a much greater latitude is permissible, and therefore are better suited to manufacture under Chinese conditions. Chinese pig has been shipped from these works to the United States, an operation subject to repetition, as steamers outbound are always seeking weight cargo to offset the usually light material, such as hemp and matting, China's staple exports, and are eager to carry pig metal at a very low freight rate.

Other lines of constructive development that need serious attention are harbor improvement, irrigation, land reclamation, and river control. Of irrigation the Chinese themselves have done something with crude and simple methods, but of river conservancy work and land reclamation but little has been done, and the opportunity is great. The most serious step in this line is the proposed Huai river improvement, with incidental land reclamation, in northern Anhui and Kiangsu, through which district the Yellow River once flowed. To-day this area of 12,000 square miles, or half as large again as the State of Massachusetts, has practically no drainage, certainly not during a wet season. The soil is exceedingly fertile and capable of raising a generous exportable surplus over all local requirements. As a matter of fact, owing to inundations two crops out of three are lost. Nearly every year for some years past the American Red Cross Society has raised considerable sums to aid the flood-stricken people, and to obviate this it was suggested to drain the territory, reclaim the lands from floods, and remove the cause of the trouble. A favorable report upon this project was made by Mr. C. D. Jameson, American Red Cross Engineer to China, which has recently been approved by a special board of engineers under Colonel William L. Sibert, who made detail plans for the work. This district is not the only one in China where similar improvements can, with profit to the promoters, and should, for the sake of the people, be undertaken.

The great stumbling block to the new development in China is the government itself, which lacks vitality, as it is a government neither of nor over the people. It is not now a democracy, and it has not been for some centuries an all-powerful autocracy. There are no general laws, nor even generally recognized customs, that can deal properly and thoroughly with railways, mines, land reclamation, river improvements, highways, etc. Even if certain government officials technically have the power and authority to create or to permit the creation of public works, they invariably shrink from exercising their powers until, regardless even of Chinese law, they are assured of the support of the local "gentry," a class too frequently controlled by prejudice and quite ignorant of the remedy for their own local troubles of poverty and suffering, even to the extent of frequently-recurring famines. In governmental matters, as in most other things, the Chinaman just reverses usually-accepted standards. He owes his first allegiance to his clan, afterwards to his province, and last to his nation. The consequence is that a government decree may meet with such violent local opposition as to cause its defeat. This is fully realized by high officials and is perhaps the cause for their timidity and reluctance to come to any decision until local approval is assured. After many years of bitter experience the people have no confidence in the officials, who are regarded—and, unfortunately by past experience, with justification—as engaged in enriching themselves at the people's expense. Fear of officials and antipathy to foreigners have made the Chinese very suspicious of all schemes concocted by these two dreaded classes, and has, on one hand, retarded development and, on the other, kept in force the vicious and wasteful method of Chinese concessions. When this barrier is broken down, when foreign political intrigue is eliminated, when a free field is established for industrial development, there will undoubtedly be in China a great opening for the American engineer. Those who, with friendly eyes, have been watching Chinese affairs with hopeful expectation of such development have on many occasions during the past 50 years thought that the moment had arrived, only to find that but a small advance had been made. Again another crisis has arisen in the great war now in progress. If this will jar China loose from some of its shackles, there will be some gain to offset the otherwise appalling loss.

Magnetic Habits of Alloy Steels. J. A. MATTHEWS. (*Proc. Amer. Soc. Testing Materials,* 1914.)—The magnetic properties of hardened alloy steels are shown to vary with the physical characteristics of the metal. Alloys hardened by quenching in oil give a lower permeability and residual magnetism but a higher coercive force than those quenched in water. The size of the cross-section of the metal also has an influence, varying according to the hardness of the metal.

Study of the Strength of Non-ferrous Castings. L. P. WEBBERT. (*Amer. Soc. Testing Materials,* 1914.)—Tensile tests of Cu-Sn and Cu-Zn alloys were made on test-pieces respectively cast on the outsides of big castings and cut from different portions of solid castings. With Cu-Sn alloys (typically Cu 88, Sn 10, Zn 2) greater tensile strength and elongation were obtained on metal which had cooled quickly than on that taken from the inside of a solid casting, the highest results being given by the cast test-pieces. The use of externally cast test-pieces may therefore give misleading (high) results. Similarly, where little machining was required to make the finished test-piece, the thinner specimens gave the higher results, owing to the cross-sectional proportion of quickly-cooled "skin" being greater. With the Cu-Zn alloys the differences observed with test-pieces taken from different positions were much smaller, and an externally cast specimen represented very closely the strength of the casting as a whole.

Some Notes on Chilled Cast Iron. E. B. TILT. (*Proc. Amer. Soc. Testing Materials,* 1914.)—The variations in the properties of cast iron according to its composition and the effect of chilling were examined with a view to determining the most suitable material for car wheels. Wheels were tested by allowing weights to fall repeatedly from definite heights until a flange was broken off, and also by submitting them to a rapid temperature change. The nature of the defects to which the wheels are subject is discussed. Satisfactory metal can be obtained both from charcoal pig iron and from material prepared from coke pig iron, steel scrap, and ferromanganese. The carbon content should not exceed 3.5 per cent. The metal was found to be brittle in proportion to the degree of chilling.

Lead and the End Product of Thorium. A. HOLMES and R. W. LAWSON. (*Phil. Mag.,* xxviii, 823.)—It has been suggested recently that the end products of the disintegration of uranium, thorium, and actinium are all isotopic with (*i.e.,* indistinguishable chemically from) ordinary lead.

This view has been practically established so far as the end product of uranium (uranium lead or radium G) is concerned, the ratio Pb : U being constant in minerals of the same geological age and increasing with the age in the case of minerals of varying age. Analysis of a number of Devonian minerals and comparison of published analyses of minerals of varying geological age have now shown that there is no constancy in the Pb : Th ratios for minerals of the same age, and hence that thorium E (thorium lead) cannot be a stable isotope of lead, but must disintegrate slowly, losing radiations which have so far escaped detection (the half period of decay has been calculated to be 6×10^5 years by R. W. Lawson, *Nature,* July 9, 1914). It is suggested that the stable end products of thorium and actinium are respectively bismuth and thallium.

MODERN STEELS AND THEIR HEAT TREATMENT.*

BY

ROBERT R. ABBOTT, E.M., Met.E.,

The Peerless Motor Car Company, Cleveland, Ohio.
Member of the Institute.

STEEL is an alloy. In its most simple form it is made up of two components: iron and a carbide of iron technically known as cementite and having the chemical symbol Fe_3C.

Commercial steel always has at least four other elements present: phosphorus, sulphur, manganese, and silicon. Phosphorus and sulphur are usually objectionable impurities, while manganese and silicon are required in the finished steel to insure good material. The total amount of these four elements contained in an ordinary commercial steel is less than 1 per cent. The influence of the average variation in all of these impurities is slight upon the physical properties of the steel, compared with the effect of the carbon. We can, therefore, eliminate them in our consideration of the structure of commercial steel.

The carbon is the main factor in influencing variations in the physical properties. It varies from practically nothing in wrought iron to about 1½ per cent. in high carbon tool steel. A variation of 0.1 of 1 per cent. of carbon will affect the tensile strength of annealed steel about 8000 pounds per square inch. This seems rather remarkable, but it is more readily understood when the following facts are considered: the carbon exists as cementite, which is fifteen times as heavy as the carbon of which it is composed. In steel this cementite occurs intimately mixed with about 6½ times its own weight of iron. One part of carbon, therefore, makes up about 112½ parts of this mixture, which is known as pearlite. It is here shown under a magnification of 1200 diameters (Fig. 1).

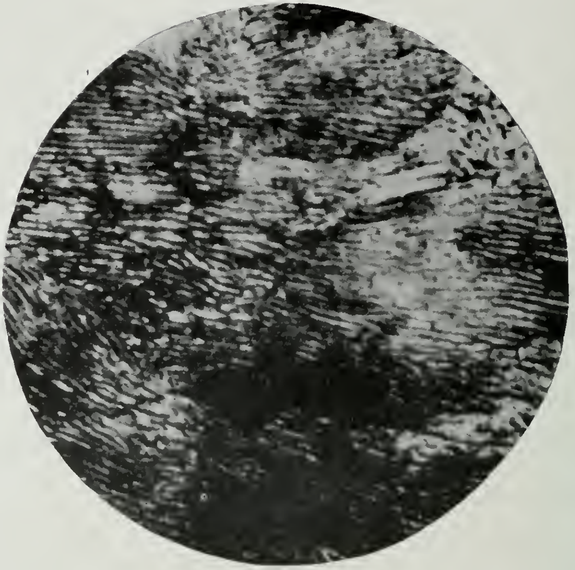
The black material is the iron, while the white is the cementite. A steel containing 0.1 per cent. carbon is then really composed of about 11 per cent. pearlite and 89 per cent. of iron.

Fig. 2 (150 diameters) shows a sample of iron. It contains

---

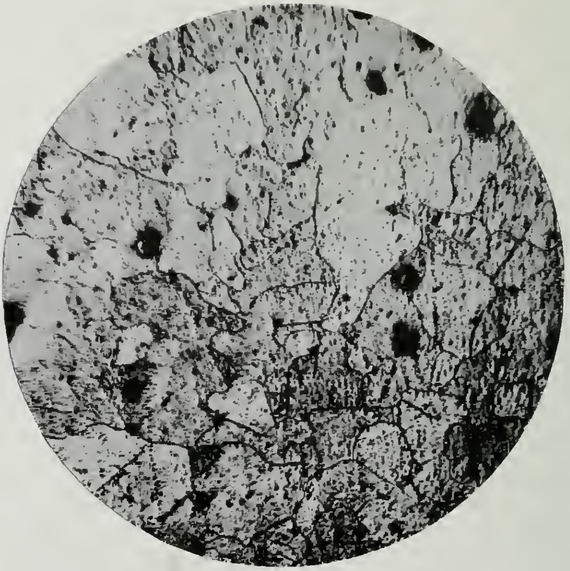
* Presented at the joint meeting of the Mining and Metallurgical Section and the American Society of Mechanical Engineers held January 14, 1915.

FIG. 1.



Pearlite. (1200 diameters.)

FIG. 2.



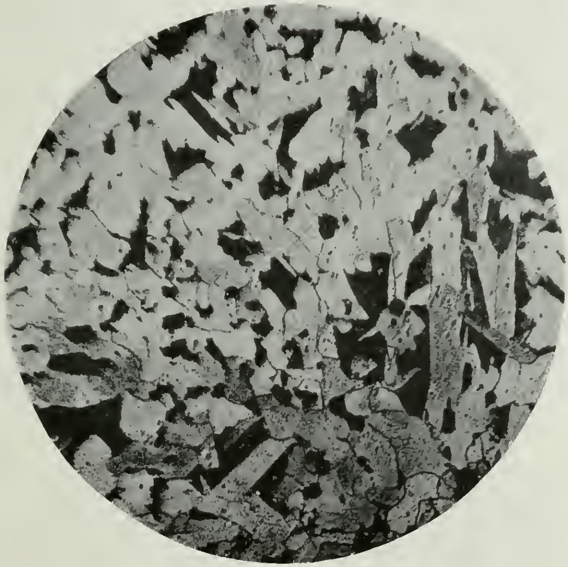
Iron. (150 diameters.)

about 0.01 per cent. carbon, which makes the structure 1 per cent. pearlite and 99 per cent. iron. This pearlite is not visible under this magnification, and, therefore, the material has the appearance of pure iron. The network of lines represents the boundary of individual crystals of iron. As the carbon increases the pearlite areas become larger and the amount of iron smaller.

Fig. 3 (150 diameters) is a microscopic photograph of a steel containing 0.20 per cent. carbon and, therefore, about 22 per cent. pearlite.

Fig. 4 (150 diameters) shows a still further increase in carbon to 0.40 per cent., which is equivalent to 45 per cent. pearlite and 55 per cent. iron.

FIG. 3.

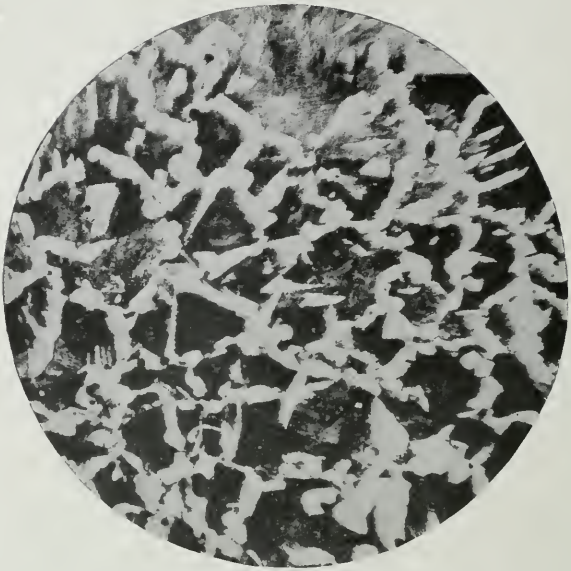


Iron and pearlite, 0.20 per cent. carbon. (150 diameters.)

Fig. 5 (150 diameters) shows an 0.80 per cent. carbon steel, which contains 90 per cent. pearlite and 10 per cent. iron, while in Fig. 6 (150 diameters) there is no excess iron and, therefore, 100 per cent. pearlite, which is equivalent to a 0.90 per cent. carbon steel.

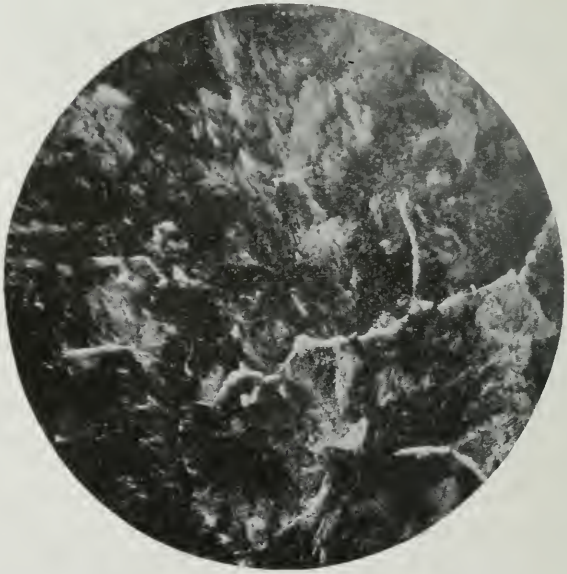
As the carbon increases above the point necessary to form 100 per cent. pearlite it must necessarily exist as free cementite,

FIG. 4.



Iron and pearlite, 0.40 per cent. carbon. (150 diameters.)

FIG. 5.



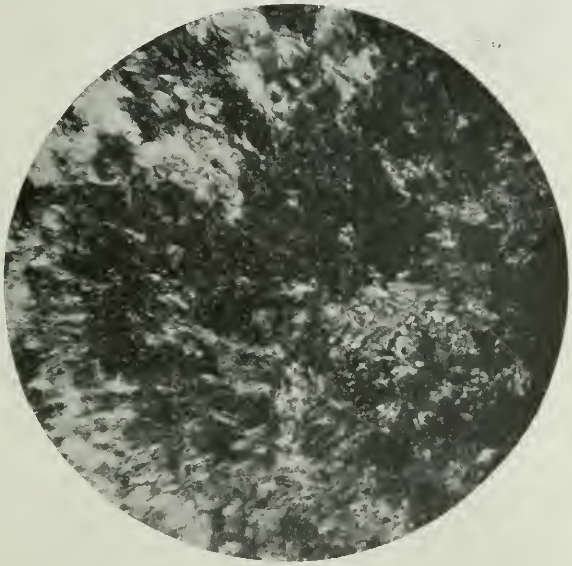
Iron and pearlite, 0.80 per cent. carbon. (150 diameters.)

as all the iron has been taken up to form pearlite when the carbon reached 0.90 per cent.

Fig. 7 (150 diameters) shows a steel with 1.4 per cent. carbon. It consists of 92.5 per cent. pearlite and 7.5 per cent. cementite.

Fig. 8 (150 diameters) is a steel containing 2.5 per cent. carbon. It consists of 24 per cent. cementite and 76 per cent. pearlite. A steel of this high carbon is rare and has no commercial application. White cast iron, which is the material from which malleable iron is made, is an impure steel of a carbon content similar to this.

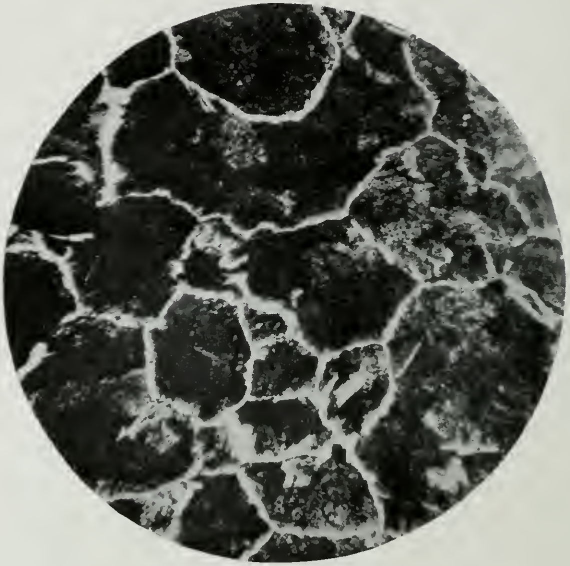
FIG. 6.



Pearlite, 0.90 per cent. carbon. (150 diameters.)

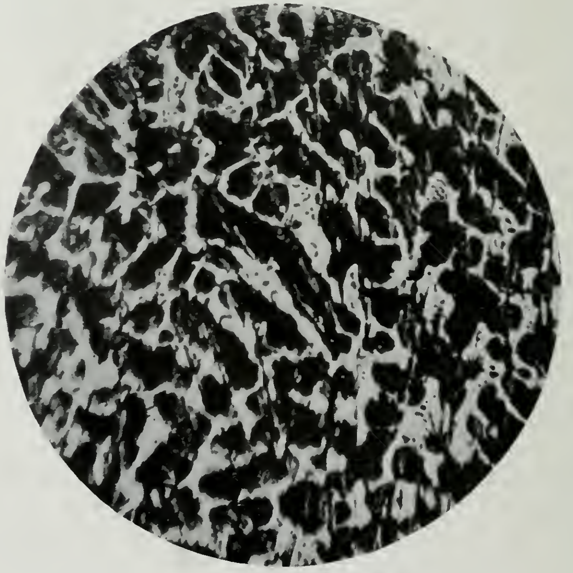
Briefly summarizing the structural condition of a series of steels of various carbon contents, we see that one containing 0.9 per cent. carbon consists of 100 per cent. pearlite. This steel is known as saturated, or, commonly, an eutectoid, steel. A steel containing less than 0.9 per cent. carbon contains pearlite and iron. Such a steel is known as an undersaturated or hypo-eutectoid steel. A steel with more than 0.9 per cent. carbon is known as a supersaturated or hyper-eutectoid steel. Fig. 9 (150 diameters) shows

FIG. 7.



Cementite and pearlite, 1.4 per cent. carbon. (150 diameters.)

FIG. 8.

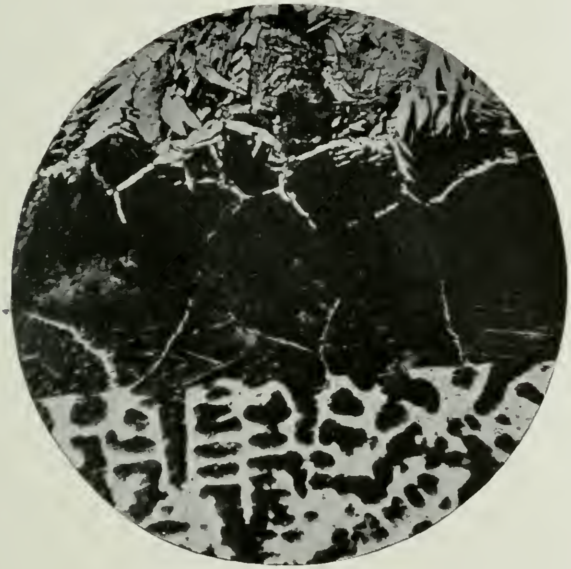


Cementite and pearlite, 2.5 per cent. carbon. (150 diameters.)

the same piece of steel containing supersaturated, saturated, and undersaturated bands. The carbon contents vary from 2.5 per cent. to 0.2 per cent.

When a piece of steel is pulled apart in a tensile machine the cross-sectional area at the point of fracture is less than that of the original bar. The amount of this difference is known as the "reduction in area," and it is a fair measure of the toughness of the steel. While the meaning of the term "toughness" is open to more or less dispute, we can consider it as the ability of the metal to distort without causing fracture. For example, a steel which can be bent through an angle of 75 degrees before fracture is tougher than one which can be bent only 25 degrees.

FIG. 9.



Undersaturated, saturated and supersaturated bands. (150 diameters.)

Now if we make tensile tests on a series of steels of increasing carbon contents we find that the tensile strength increases with the increase in the amount of pearlite, but the toughness decreases.

The tensile strength of iron is about 40,000 pounds per square inch. This can be increased by about 700 pounds for each increase of 1 per cent. pearlite.

The reduction in area for pure iron is about 80 per cent., and this is decreased by about 0.5 per cent. for each increase of 1 per cent. pearlite. For ordinary structural purposes a steel which is subject to vibration or shock is not safe with much less than 50 per cent. reduction in area. From these figures it is readily calculated that a steel with 60 per cent. pearlite, which corresponds to about 0.55 per cent. carbon, has a reduction in area of about 50 per cent. Such a steel has a strength of approximately 80,000 pounds per square inch.

Evidently, then, for a steel subjected to dynamic stresses we can safely increase its strength up to 80,000 pounds per square inch by the use of an increased carbon content; however, every additional increase in strength is obtained at the expense of the toughness. A further consideration is the fact that the hardness of the steel, and therefore the difficulty and expense of machining, increases with the increase in pearlite.

A little consideration of the above facts will show us that they are logical and what we should expect. The pearlite is composed of fine plates of pure iron strengthened and made rigid by cementite, which itself is intensely hard and strong, but very brittle.

The pearlite, then, as a mass is strong, but, due to the cementite in it, it is not as tough as pure iron. Pure iron compared to pearlite is weak but tough. A combination of the two will give characteristics consistent with the proportion of the constituents.

It is apparent that in order to obtain greater strength on the steel without increasing the amount of pearlite, or, what is the same thing, the amount of carbon, we could do at least three things: (1) increase the strength of the iron, (2) increase the strength of the pearlite, or (3) increase the strength of both. Practically, these are reduced to two, because anything which increases the strength of the iron also increases the strength of the pearlite to some extent, because of the iron in it.

This can be accomplished by adding to the steel some element or elements which will alloy with either the iron, the pearlite, or both, and increase their strength. A steel containing this extra element is known as an alloy steel. There are two classes of alloy steels: (1) those in which one or more of the normal impurities are made abnormally large, and (2) those in which one or more elements not normally present are added. To the first class belong silicon and manganese steels. To the second class, which is the more important commercially, belong nickel, chrome, chrome vanadium, chrome nickel, tungsten, and titanum steels.

As typical examples of the two methods of increasing the strength of steel we will consider nickel and chrome steels. Nickel forms a solution or alloy with the iron which is stronger than iron alone. Chromium replaces some of the iron of cementite, forming a carbide of chromium. The pearlite thus formed from the double carbide of chromium and iron is stronger and at the same time tougher than ordinary pearlite formed without chromium. The most widely used nickel steel contains 3½ per cent. nickel, while the common chrome steel has about 1 per cent. chrome. Such a nickel steel will be about 20,000 pounds per square inch, and a chrome steel about 15,000 pounds stronger than a simple steel of the same carbon content. At the same time the toughness of the nickel steel will be about the same as that of a simple steel, while for the chrome steel it will be a little greater. It is apparent, then, that the use of an alloying element to increase the strength of steel is better than to use carbon for the same purpose, as the increased strength is not obtained at the expense of the toughness.

We have seen that the relation between strength and toughness in ordinary steel can be varied by changing the relative amounts, and also the strength or toughness of two substances composing it; namely, the pearlite and iron. In either case this must be done by adding something to the steel: in the first case, carbon, and, in the second, some alloying element.

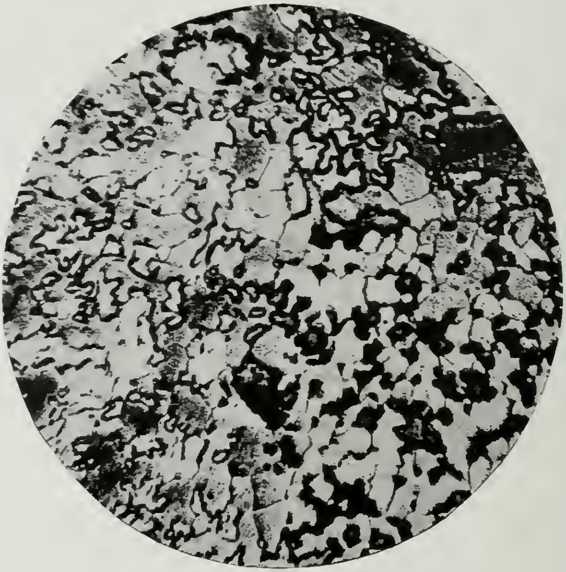
Can we not change the relative amounts of the elements or their strength by some process of heating? We will now discuss this.

Consider the same steel shown in Fig. 3. If we heat this to a temperature of 1000° Fahrenheit and suddenly cool or quench it in cold water, we will find that neither its physical properties nor its appearance under the microscope have been changed; if we increase the temperature to 1100°, we still find no change: nor will we detect any difference until we use a temperature of about 1375° Fahrenheit. Fig. 10 (150 diameters) shows a steel so treated. Comparing it to Fig. 3, we find that the iron is still present and in about the same amount, but the pearlite areas have become more or less rounded.

If we examine this structure under 1200 diameters, the same magnification which we used for the pearlite in Fig. 1, we get a structure shown in Fig. 11. The white areas are the iron, while the dark areas represent what was originally pearlite. It has now apparently coalesced, so that the original cementite and ferrite of which it was composed have merged into a single substance.

The real explanation of the change which has taken place is that the iron which originally composed part of the pearlite underwent an allotropic change at this temperature, and in its new form it is capable of dissolving to a solid solution the cementite with which it was in contact. This new solid solution is known as austenite, and by the sudden quenching time is not given for the reverse allotropic change to occur completely. It cannot be entirely prevented, and the transition substance which we really obtain is known as martensite.

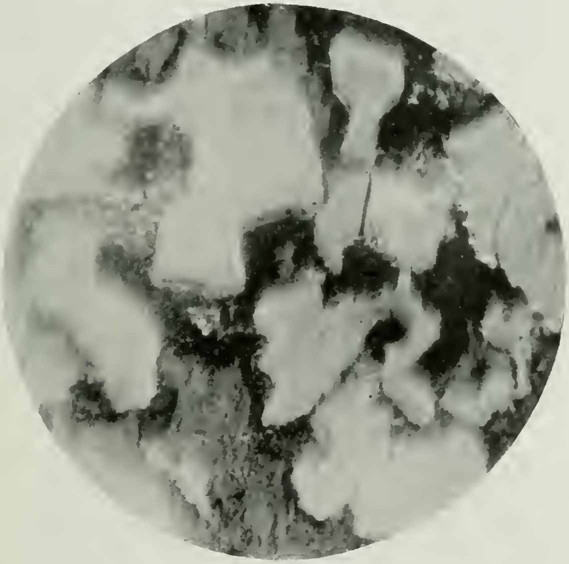
FIG. 10.



Martensite and iron, 0.20 per cent. carbon, quenched from 1375° F. (150 diameters.)

A steel thus treated is different from the untreated steel in one of its constituents, and is made up of iron and martensite instead of iron and pearlite. Martensite is much stronger but more brittle than pearlite. We should then expect that our treated steel should be stronger but less tough than the one not treated. The untreated steel of Fig. 3 has a tensile strength of about 55,000 pounds per square inch, and a reduction in area of 65 per cent. The same steel heat treated as just explained has a tensile strength of about 95,000 pounds per square inch and a reduction in area of about 30 per cent. Now these properties are very similar to those of a high carbon steel containing about 100 per cent. pearlite or 0.90 per cent. carbon. In other words, by a simple process of heat treatment we can obtain with a 0.20 per cent. carbon steel the physical strength of a 0.90 per cent. carbon untreated steel.

FIG. 11.

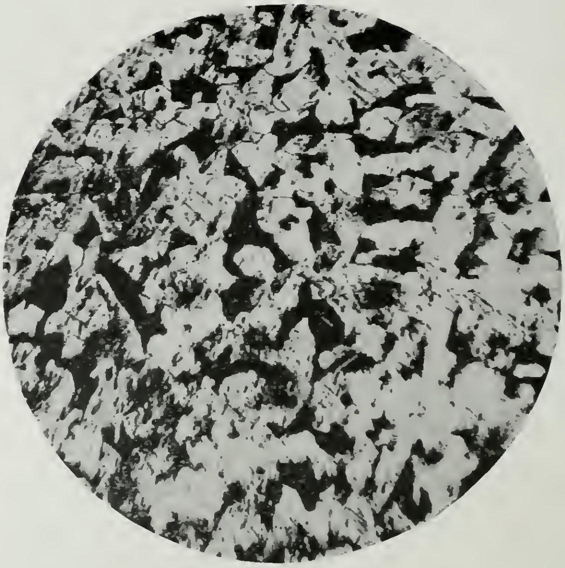


Martensite and iron. (1200 diameters.)

We have just seen that at some definite temperature the pure iron in the pearlite went into a solid solution with the cementite. Possibly at a still higher temperature we could cause more of the iron to go into such a solution.

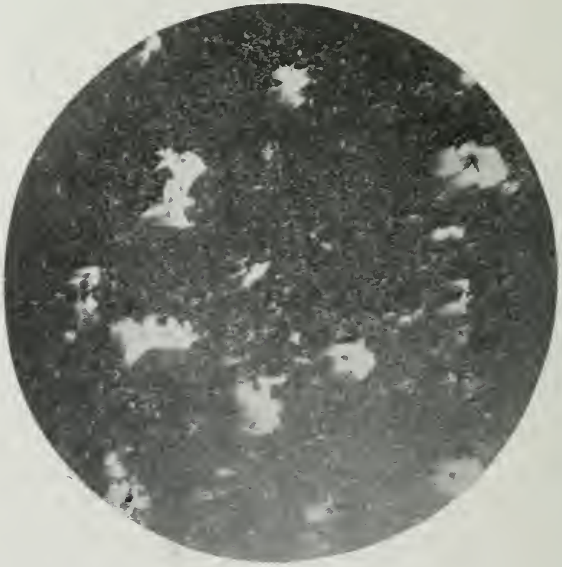
Fig. 12 (150 diameters) is a photograph of the structure of the same steel quenched from 1440°. It will be noted that the iron has decreased in amount, while the martensite has increased.

FIG. 12.



Martensite and iron, 0.20 per cent. carbon, quenched from 1440° F. (150 diameters.)

FIG. 13.

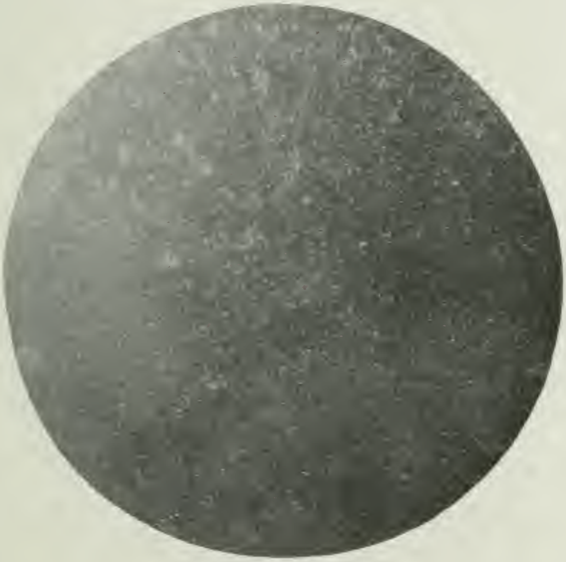


Martensite and iron, 0.20 per cent. carbon, quenched from 1525° F. (150 diameters.)

Apparently, then, as we raise the temperature we increase the saturation point of the martensite for iron; just as in a water solution we can cause more sugar to dissolve by increasing the temperature, so we can here cause more iron to dissolve by increasing the temperature.

Fig. 13 (150 diameters) is the same steel quenched still higher from 1525°. At a temperature of 1565° all of the iron will go into solution and the quenched steel will consist of 100 per cent. martensite. This is shown in Fig. 14 (150 diameters).

FIG. 14.



Martensite, 0.20 per cent. carbon, quenched from 1565° F. (150 diameters.)

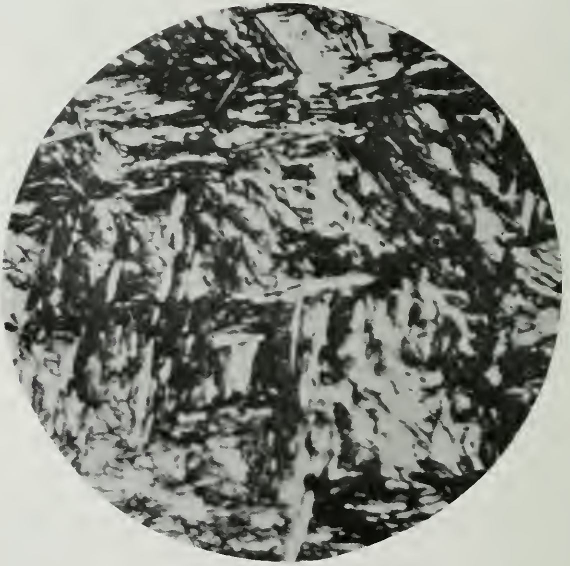
A higher magnification shows the martensite structure to be triangular, as in Fig. 15 (1200 diameters).

Now by comparing the series showing increasing carbon contents in different steels, *i.e.*, Fig. 2 to Fig. 6 inclusive, with the series Figs. 10–12–13–14, which represents the same steel subjected to an increasing temperature of quenching, it will be seen that they are very similar, in that the amount of iron constantly decreases until it becomes zero, while in the increasing carbon series the pearlite increases to 100 per cent. and in the increasing temperature series the martensite increases to 100 per cent.

If we make physical tests on the increasing temperature series, we find that the strength increases, beginning with the temperature of the first change, until final absorption of the iron, while the toughness also increases if the carbon is low. The following table will illustrate this more fully:

Untreated steel			Heat-treated steel, 0.20 per cent. carbon		
Per cent. pearlite	Strength	Toughness	Per cent. martensite	Strength	Toughness
25	55,000	65	25	95,000	30
50	75,000	55	50	98,000	40
75	90,000	45	75	100,000	50
100	105,000	35	100	105,000	55

FIG. 15.



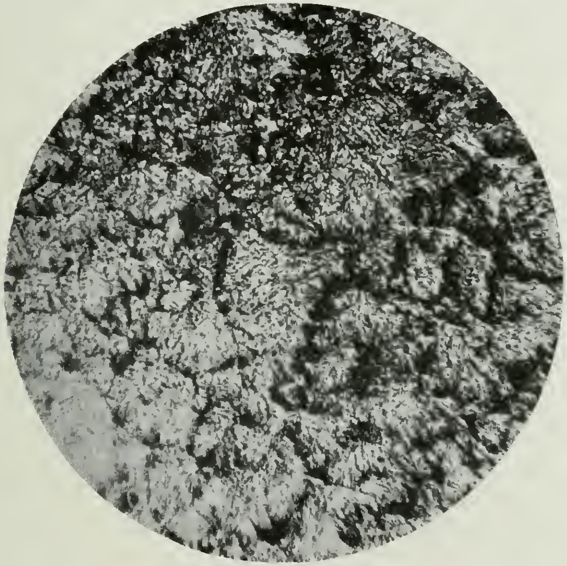
Martensite. (1200 diameters.)

The temperature at which the pearlite first changes is known as the lower critical temperature, and is designated by the symbol "Ac_1." The temperature at which the absorption of iron is complete is known as the upper critical temperature, and is designated as "Ac_3." There is an intermediate critical temperature, which we will not consider now.

It is apparent that of two steels containing different percentages of carbon, and therefore different percentages of pearlite, the one containing the more pearlite will have less iron to dissolve, and therefore the temperature of final absorption will be lower. In other words, the upper critical temperature is lowered by an increase in the carbon content. If the steel is all pearlite, *i.e.,* contains 0.90 per cent. carbon, its upper and lower critical temperatures will coincide.

With some steels the best results are obtained by quenching just at the absorption point, while with others a higher temperature is necessary. The metallurgist must know the amount of this variation for different types of steels.

FIG. 16.



Martensite and troostite, first stage. (150 diameters.)

The heat treatment of an alloy steel is exactly the same in principle as that explained above for plain carbon steels, the alloying elements giving increased strength as well as increased toughness to the heat treated, in the same manner as it did in the untreated steel.

From the foregoing it is apparent that a steel heat-treated to bring out high strength will consist of 100 per cent. martensite, no matter what amount of carbon there was originally present, nor whether alloying elements were there or not. Evidently, then, martensite will have a varying composition. Under the microscope there is very little difference in appearance, no matter what the composition. Since martensite is really formed from a solution of cementite in iron, a high-carbon steel will form a stronger solution than a low-carbon one, just as we can have a strong or weak solution of salt in water. Alloying elements in the martensite do not cause any difference in its structure any more than a little sugar would cause a difference in the appearance of a salt-water solution. These alloying elements, however, have a very decided influence upon the position of the critical temperature; for example, 0.1 per cent. manganese lowers the upper critical temperature 6 degrees, while it has practically no effect upon the lower critical temperature; 0.1 per cent. chromium raises the lower critical temperature 4 degrees when nickel is absent, but with nickel present it raises it only 3 degrees, but in neither case does it have any appreciable influence upon the upper critical temperature.

The business of the metallurgical engineer is to know absolutely the influence of all elements upon these critical temperatures.

In general, these martensites made from a steel containing more than 0.2 per cent. carbon have not enough toughness for their strength, and to remedy this the steel is given a second low heat, commercially known as a drawing heat, which allows a certain amount of transformation to take place in the martensite, and reduces its strength but increases its toughness. By varying the final heat, an unlimited number of combinations of strength and toughness are available.

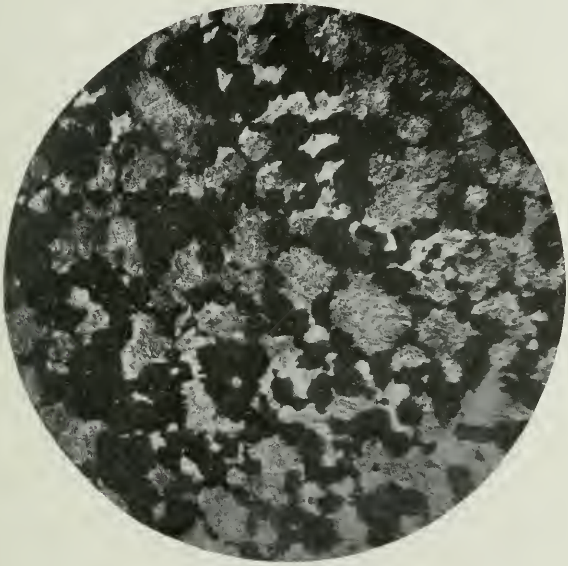
Some of these transformation stages have definite characteristics. Fig. 16 (150 diameters) shows one stage. The lighter-colored material is martensite, while the black spots are known as troostite.

In Fig. 17 (150 diameters) the same constituents are shown, but in a more advanced state.

As the drawing temperature is raised still higher the microstructure of the steel becomes extremely fine and it is known as sorbite. This is really an imperfect pearlite intimately mixed with the iron.

Broadly summarized, the process of heat treatment consists in transforming an alloy from a mechanical mixture of two substances into a homogeneous solution of a single substance. This very fact gives to a heat-treated steel one of its most valuable advantages over the untreated steel; namely, its ability to withstand repeated shocks or vibrations, or, as it is popularly expressed, "fatigue-resisting power." The reason is obvious: an alloy composed of two dissimilar substances has mechanical boundaries between them. This fact is a source of weakness under repeated stresses, the reasons for which are more or less complicated. An untreated steel contains these boundaries; a correctly heat-treated steel does not.

FIG. 17.

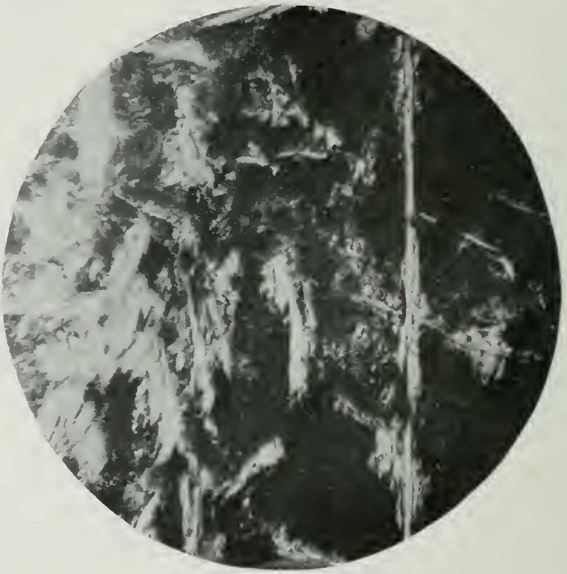


Martensite and troostite, second stage. (150 diameters.)

There is a still further advantage based upon a different consideration. A steel with a tensile strength of, say, 60,000 pounds per square inch, if subjected to repeated reverses of stress of any magnitude, will finally break after a definite number of these reversals; as the magnitude of these stresses approaches the actual strength of the steel, the number of reversals necessary to cause a break rapidly decreases; as a consequence of this fact, a comparatively slight increase in the strength of a piece of steel will increase way out of proportion its resistance to fatigue break. Therefore it is frequently desirable to heat-treat a piece of steel to give it an added factor of safety under shock or alternate stresses, even though its static factor of safety is ample.

In supersaturated steels,—that is, those containing more than 0.90 per cent. carbon,—we have present cementite and pearlite. Most tool steels belong to this class. In the heat treatment of such a steel the pearlite changes to austenite at the same temperature which we found for an undersaturated steel. As the temperature is raised above this point the excess cementite begins dissolving into this austenite, just as the iron did in a lower carbon steel, until at a definite temperature all of it is dissolved, and we have, as before, austenite. The cementite is more sluggish in dissolving into the austenite than the iron, and the reaction requires more time to complete. As we have previously seen, cementite is extremely brittle and hard; it occurs usually as sheets in the pearlite

FIG. 18.



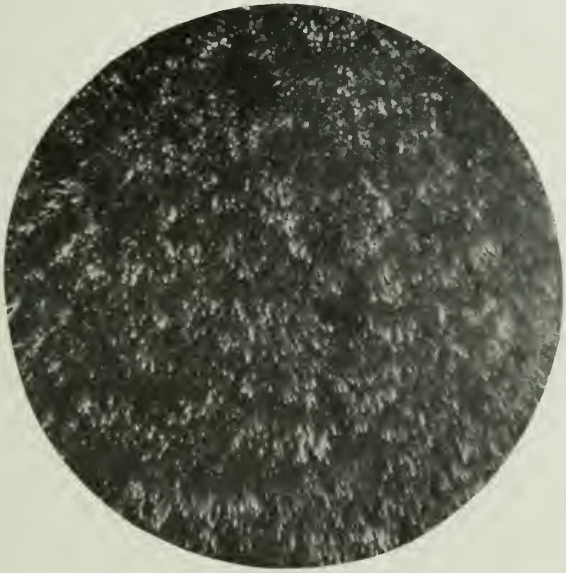
Cementite needles. (350 diameters.)

or thin envelopes surrounding grains of pearlite. These two types are shown in Fig. 18 (350 diameters) and Fig. 7 (150 diameters).

A piece of tool steel which has been previously slowly cooled from above the temperature at which the last of the cementite went into solution will contain the cementite in one of these two forms.

If it is hardened at the lowest possible temperature its pearlite will be changed to martensite, while its cementite will be unchanged. These sheets or envelopes of cementite will cause the steel to be extremely brittle, and is a source of many of the troubles of the steel user.

FIG. 19.

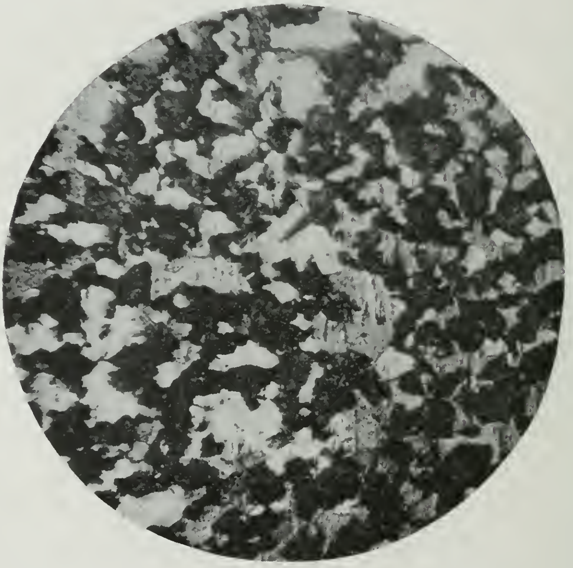


Cementite globules. (350 diameters.)

Now if we quench from above the upper absorption point we get rid of this cementite, but the steel is somewhat softer because of its absence. The structure of the steel has also been coarsened by the high temperature, which causes it to be brittle. Now if the coarsened steel is again reheated slightly above the lowest hardening temperature, the cementite will be precipitated out of the solution, but, instead of being in sheets or plates, it will occur as fine dots, which give extremely good wear and have practically no effect of brittleness. A steel thus treated is shown in Fig. 19 (350 diameters). This same arrangement of cementite can be formed by heating the steel to just above the lowest hardening temperature and holding at this temperature for some time.

In an alloy steel the influence of carbon is reduced, and this reduction is greater the higher the percentage of alloy. For structural purposes the carbon of alloy steels rarely exceeds 0.50 per cent.; those containing less than 0.25 per cent. are usually used for parts which are to be surface-hardened by the carbonizing process, and above 0.25 per cent. for parts which are to be subjected to stresses which do not require a hardened surface.

FIG. 20.

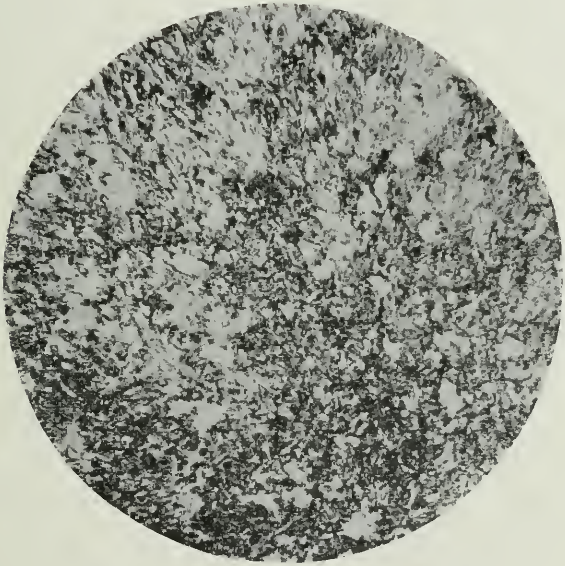


Core of carbonized steel, single quench. (150 diameters.)

In the carbonizing process the outer surface of a low-carbon steel has its carbon content raised by heating in contact with carbonaceous material. The depth of penetration of this high-carbon shell and also the percentage of carbon it contains are functions of the carbonizing material used and the temperature and time of carbonization in general; the outer surface should be a supersaturated steel, and therefore its treatment comes under that of tool steel, which we have just considered.

To produce a correctly heat-treated, carbonized article we have four functions to consider: (1) the chemical analysis of the steel; (2) the carbonizing material; (3) the time of carbonization, and (4) the temperature of carbonization. These should be adjusted so that the upper absorption point of the iron of the core shall exceed that of the cementite of the case. Under these conditions, if the steel is quenched from above the absorption point of the core this will be entirely martensitic, and at the same time the cementite sheet or net of the case will be absorbed, so that it will also be martensitic.

FIG. 21.



Core of carbonized steel, double quench. (150 diameters.)

Now in order to obtain the maximum hardness on the surface this cementite must be precipitated, as shown in Fig. 19, by a low quench from the hardening temperature. During this second quench the iron of the core will also be precipitated out in practically the same globular form, with this difference: there being more excess iron than excess cementite in the core, the iron will precipitate in larger particles and will not have the characteristic globular appearance.

A comparison of the difference in structure of the core of a piece of carbonized steel with a single hardening heat and this double refining and hardening heat is shown in Figs 20 and 21. In both cases we have the same amount of martensite (black) and iron (white) present, but the mixture is much more intimate and fine in Fig. 21 (double quench). This increases enormously the toughness of the finished steel.

DISCUSSION.

MR. H. V. WILLE (*Metallurgist, The Baldwin Locomotive Works*).—The theory of heat treatment has been understood by metallurgists for many years, but this has been largely applied in a practical way only during recent years. Some years ago Dr. Sargeant, who is now connected with the Crucible Steel Company of America, exhibited a small experiment at the Institute which showed in an interesting way the basis of all heat treatment of steel. He heated in a flame of a Bunsen burner a thin plate until he obtained a red spot. Upon removal from the flame he showed that this spot gradually decreased in brightness until a certain temperature was reached, whereupon the fall of the temperature was arrested and the spot glowed with a marked increase in luminosity, showing that some internal change had taken place in the molecular structure in the steel which caused the elevation in temperature in a manner similar to that produced by the combination of sulphuric acid and water. If the steel is quenched at this temperature it will retain its molecular structure, and if examined it will be found that steel so quenched is of maximum hardness, with a less loss of ductility for that particular grade, and, furthermore, the molecular structure will not be changed unless the steel is again heated above this critical or recallescence point. It therefore follows that a steel so quenched can be annealed below this temperature without change in the molecular structure, but with a great increase in ductility. A steel so treated has a much higher elastic limit and a much greater reduction of area than steel which has been subject to the ordinary annealing process. The sole advantage of all of the modern high-grade steel consists solely in an increase in the elastic limit, so that the designer is enabled to reduce the weight or size of any detail by the use of a higher unit stress, or to increase the factor of safety by the retention of the same unit stress as in a straight annealed steel.

Extremely high elastic limits can be obtained by the use of the various alloys to assist the hardening effect of carbon, such as nickel and chromium, or of the various tertiary alloys, such as chrome nickel, chrome vanadium, or chrome titanium. Steel can be produced having an elastic limit of 150,000 pounds with sufficient ductility to prevent failure by shock by the use of some of these alloys with proper heat treatment, so that engineers are able to design parts with unit stress as high as 100,000 pounds per square inch in place of about 20,000 pounds per square inch for a straight carbon annealed steel. It is hard to grasp the great benefits derived from this enormous increase in the elastic limit. I do not, however, feel that the possibilities of the use of straight carbon, heat-treated steel have been utilized to the fullest extent. This condition results from the fact that metallurgists write the specifications to which steel is purchased, and the chief object of the metallurgist is to secure a steel of maximum ductility. The designing engineer, however, is not concerned about the ductility of the steel, but desires a steel having a maximum elastic limit; but the manufacturer is unable to produce this steel for the designer because of the ductility requirements in the specification.

Mr. James E. Howard made extensive experiments on test on rotating shafts. These results showed that the high-carbon, heat-treated steel withstood as many rotations as the more ductile alloy steel, so that it would appear that equally good results could be obtained by the use of the cheaper high-carbon, heat-treated steel as is obtained from the use of the more expensive and more ductile alloy steel. These views seem to be borne out both by the experience of automobile builders and railroads. I recall going through the principal automobile factories in France, about ten years ago, and was shown with a great deal of pride such parts as axles, steering gears, etc., which were bent double because they were made from a very low carbon ductile steel, but the experience of a few years demonstrated an inordinate number of failures from this grade of steel, and the automobile builders then went to the extreme of using the extremely high grade alloy steel, which gave better results, notwithstanding the fact that it possessed less ductility than the carbon steel.

The railroads met with the same experience, and the first experiments in the use of steel in substitution for iron were made with low-carbon steel having the same physical properties as wrought iron. A large number of failures followed this substitution, but they were eliminated by the use of steel having a tensile strength of about 80,000 pounds per square inch. This grade of steel is successfully used in railroad service, and there is a gradual tendency to go to even steel of higher carbon having a tensile strength of about 110,000 pounds per square inch. Such steels have been used in an experimental way and have fully proved their value in comparison with the higher-priced alloy steels having greater ductility.

Artificial Twin Crystals of Tin. P. GAUBERT. (*Comptes rend.*, clix, 680.)—If melted tin be allowed to solidify between plane glass surfaces and the polished face be then etched with hydrochloric acid, the outlines of the crystals, some rectangular and others triangular, may be recognized. If solidification has been slow, single crystals may extend over several square centimetres. If the lamina be punctured by a sharp blow with a needle-point, there is produced: (1) on the opposite side a cross in relief with branches equal or unequal in length, according to the orientation of the crystal surface; (2) two or three series of shining parallel bands, 0.5 mm. in width, extending from the point pressed to the edges of the crystal and making an angle of several degrees with the surface of the lamina. The angle between these bands varies with the crystalline orientation of the surface. Whatever the form of the outline of the crystal (*e.g.*, rectangular) as revealed by etching with hydrochloric acid, these bands always bound triangular areas, so that molecules originally arranged in a prismatic face of the crystal undergo re-orientation so as to bound a pyramidal face. The formation of similar bands occurs when a sheet of tin is bent, and is probably the cause of the "cry" of tin.

Calorizing: A Protective Treatment for Metals. H. B. C. ALLISON and L. A. HAWKINS. (*Gen. Elect. Rev.*, xvii, 947.)—Describes, without details, a process discovered by T. Van Aller of heating metals in revolving drums with mixtures containing finely-divided aluminum, by which a surface alloy containing Al is produced. In the case of copper the alloy thus formed is of the nature of aluminum bronze, but is more resistant to the action of heat. Similar results are obtained in the case of iron and steel, and instances are given and illustrated in which treated material has been subjected to a temperature of 900° for four hours without burning. The process seems to be useful as a method of treating iron which is to be used under oxidizing conditions at high temperatures.

THE ORGANIZATION, CHARACTER OF PERSONNEL, SCOPE OF WORK, AND METHODS OF OPERATION AND CONTROL OF A LARGE MUNICIPAL HIGHWAY DEPARTMENT.*

BY

WILLIAM H. CONNELL,

Chief, Bureau of Highways and Street Cleaning, Philadelphia, Pa.

Before discussing the organization, character of personnel, and methods of operations it might be well to consider the scope of work that should come under the control of a large municipal highway department. The activities coming under the jurisdiction of such a department would be:

> The design of all work pertaining to the highways, including parkways, park drives, and small highway bridges.
>
> All engineering work relative to lines, grades, inspection of construction, etc.
>
> The construction and maintenance of all highways, including street pavements, country roads, parkways, park drives, etc.
>
> The placing of sub-surface structures and encroachments, including all underground conduits, pipe lines, service connections, vaults, steps, street signs, stands, etc.
>
> Permits and licenses for vehicles of all kinds.
>
> Street cleaning.
>
> Collection and disposal of ashes.
>
> Collection and disposal of rubbish.
>
> Collection and disposal of garbage.

It is only necessary to glance over the scope and character of the work outlined to become convinced of the fact that, no matter how able the personnel may be, ease of operation, economy, and efficiency in controlling the different branches of work will vary with the character of organization under which the department is operating.

In looking up the definition of the word organization, the two following interpretations were unearthed from the Encyclopædia Britannica:

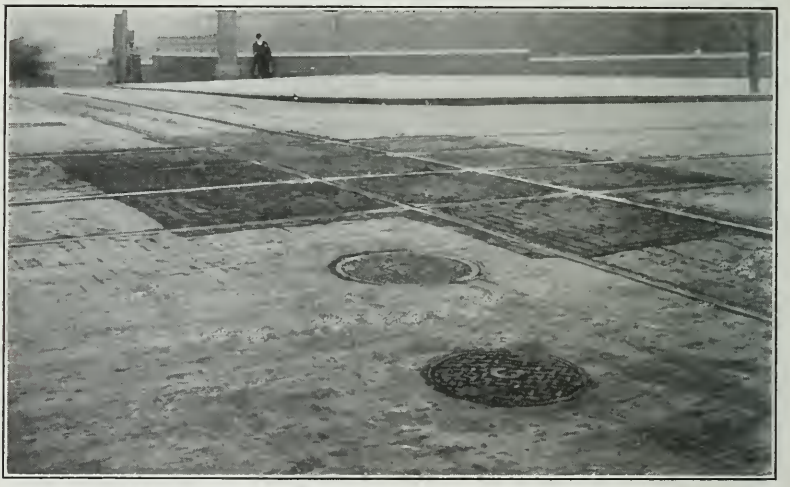
---

* Presented at the meeting of the Mechanical and Engineering Section held January 7, 1915.

> "The process of disposing or arranging constituent or interdependent parts into an organic whole."
>
> "The process of arranging or systematizing, specifically, the process of combining parts into a coördinated whole."

A better definition with particular reference to highway organizations would be:

> "The combination of corelated integral parts into a whole to systematize and simplify the operation, and bring about a maximum of efficiency in the service rendered with a minimum of friction."



Dressed granite block railway intersection on wood block street, Twenty-third and Market Streets.

The perfecting of such an organization is the real problem and grows in importance, depending upon the number of activities and volume of work coming under the jurisdiction of the department. The fundamental principles involved in the planning and operating of a successful organization are the same whether it be a state or municipal highway department, though the activities are of a somewhat different nature. The difficulties to be surmounted depend largely on whether the project consists of planning an organization for a new department, or—which is more

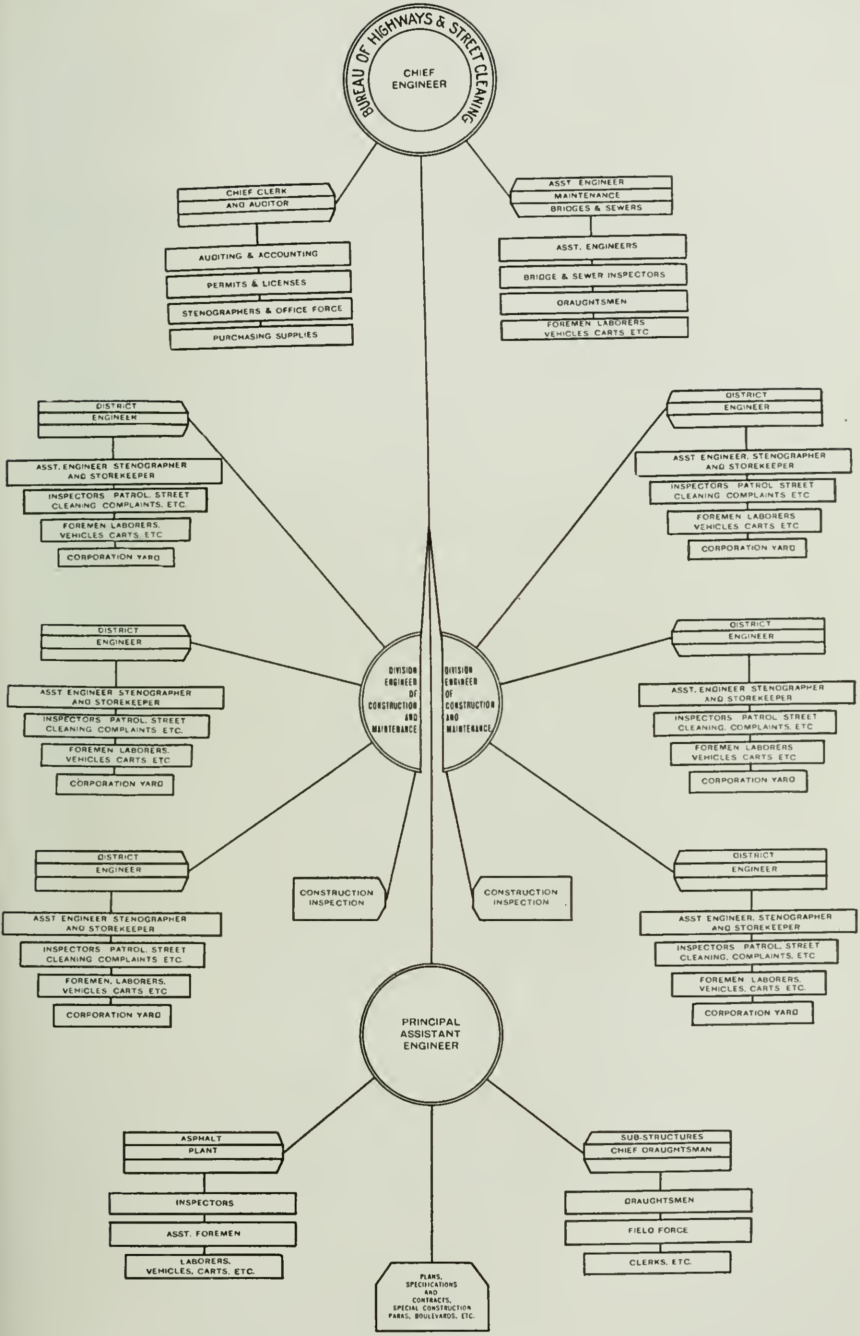
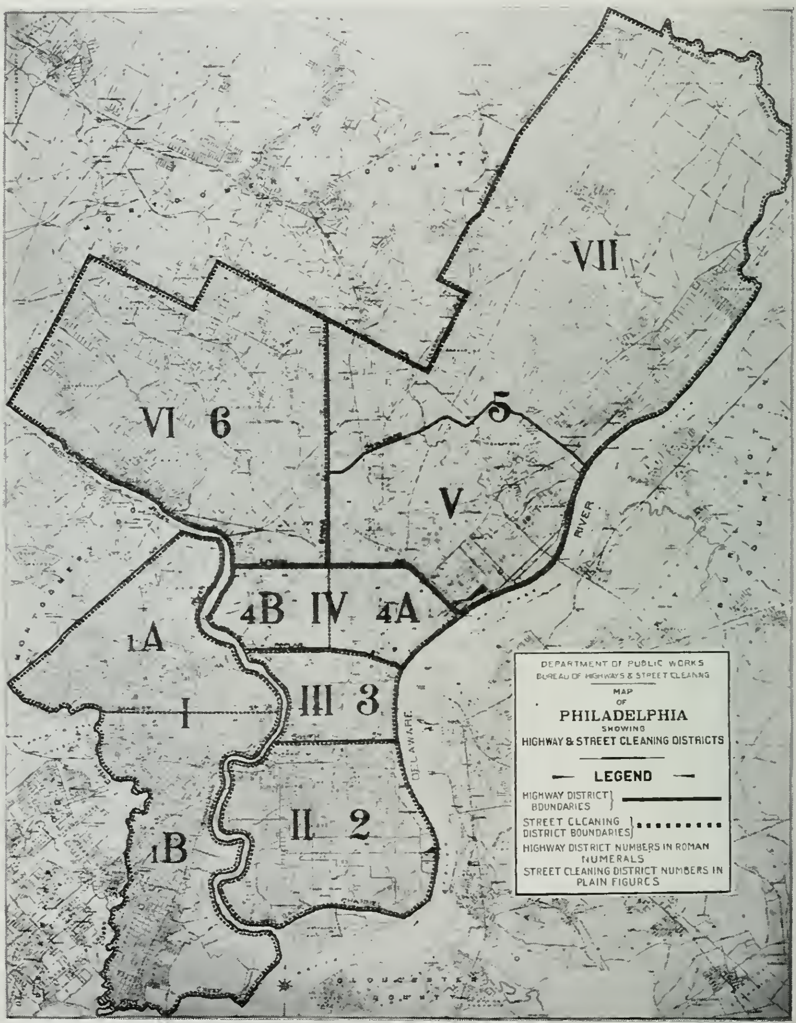

BUREAU OF HIGHWAYS & STREET CLEANING
CHIEF ENGINEER
CHIEF CLERK AND AUDITOR
AUDITING & ACCOUNTING
PERMITS & LICENSES
STENOGRAPHERS & OFFICE FORCE
PURCHASING SUPPLIES
ASST ENGINEER MAINTENANCE BRIDGES & SEWERS
ASST. ENGINEERS
BRIDGE & SEWER INSPECTORS
DRAUGHTSMEN
FOREMEN LABORERS VEHICLES CARTS ETC
DISTRICT ENGINEER
ASST. ENGINEER STENOGRAPHER AND STOREKEEPER
INSPECTORS PATROL. STREET CLEANING COMPLAINTS. ETC
FOREMEN LABORERS. VEHICLES CARTS ETC
CORPORATION YARD
DIVISION ENGINEER OF CONSTRUCTION AND MAINTENANCE
DIVISION ENGINEER OF CONSTRUCTION AND MAINTENANCE
CONSTRUCTION INSPECTION
CONSTRUCTION INSPECTION
PRINCIPAL ASSISTANT ENGINEER
ASPHALT PLANT
INSPECTORS
ASST. FOREMEN
LABORERS. VEHICLES, CARTS, ETC.
PLANS, SPECIFICATIONS AND CONTRACTS, SPECIAL CONSTRUCTION PARKS, BOULEVARDS, ETC.
SUB-STRUCTURES CHIEF DRAUGHTSMAN
DRAUGHTSMEN
FIELD FORCE
CLERKS, ETC.

Chart showing the present organization of the Bureau of Highways.

often the case—the reorganization of an existing department. The latter, of course, is the far more intricate problem and one that will be outlined in an endeavor to define some of the principles involved and the difficulties to be met.


VII
VI 6
5
V
RIVER
4B IV 4A
1A
I
III 3
DELAWARE
II 2
1B
DEPARTMENT OF PUBLIC WORKS
BUREAU OF HIGHWAYS & STREET CLEANING
MAP OF PHILADELPHIA SHOWING HIGHWAY & STREET CLEANING DISTRICTS
LEGEND
HIGHWAY DISTRICT BOUNDARIES
STREET CLEANING DISTRICT BOUNDARIES
HIGHWAY DISTRICT NUMBERS IN ROMAN NUMERALS
STREET CLEANING DISTRICT NUMBERS IN PLAIN FIGURES

The three principal factors to be considered are:

1. The planning of the organization.
2. The character of the personnel.
3. Systematizing the work.

Due weight must be given to each one of these elements.

1. *Planning the Organization.*—This must be done with a view to the future, having in mind the passage of the necessary legislation to put the department on a thorough business basis, and still must be sufficiently elastic to cope with existing conditions, as most of the operations coming under the jurisdiction of a highway department are of such a nature that they should not be put aside pending proposed legislation or investigations with a view to the reorganization of the department. This, however, is often the case, not only with reference to highway but other municipal, state and government departments, especially in changes of administration, where well-intentioned officials

Standard sign used on each section of the service test road, giving detailed information on the character of pavement.

plunge into reorganization that would ultimately place the work on a higher plane, but which often results in a great financial loss through a cessation of the activities of the departments. It is obvious to all those familiar with management on a large scale that this cannot be emphasized too strongly as one of the most important considerations in the problem of organization. It is far better to turn the work out under what might not be an ideal organization, using the necessary safeguards to see that it is properly done, than to hold up the work to the great inconvenience of the public, and with a resultant financial loss through interest charges on appropriations already made and depreciation on existing plant, to say nothing of the loss due to carrying the overhead charges, and the deterioration of roads and pavements due to lack of maintenance.

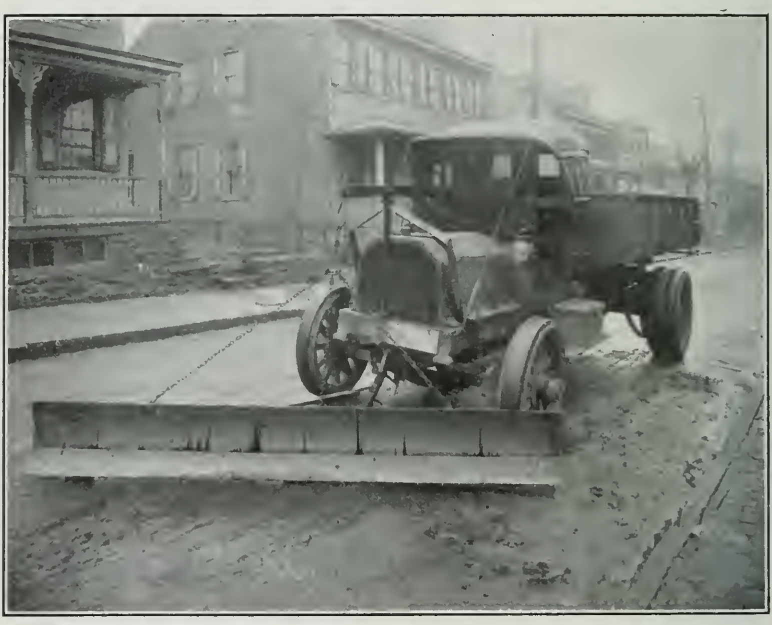
Typical of the condition of a large number of asphalt streets before and after improvement, 1912.

Typical of the condition of a large number of country roads before and after improvement, 1912.

Reorganization, to be constructive, must be brought about gradually. The primary consideration in the planning should be to centralize the control of the work, not only in so far as it relates to the head of the department, but this principle should be carried right down through the organization, which means grouping the activities and combining them where practicable, so that not only will the head of the department be familiar with all the activities, but the entire supervising force will be trained to direct all branches of the work. This will do away with shifting responsibility, which is so often the case where the maintenance and construction work are under separate divisions, and will tend to make the organization a more stable and lasting one, as the whole force will be working as a unit and, being familiar with all branches of the work, each and every one will have an equal opportunity to advance.

Street-cleaning foreman in uniform.

The tendency of the day is to standardize and control work in a manner that will not only conserve energy and do away with unnecessary duplication, in so far as individual effort is concerned, but to concentrate our forces so that we can efficiently and economically carry on our operations along the lines of least resistance, as ease of operation is one of the essential factors to be regarded in planning any working organization. There is no step that would accomplish more in this direction than the combination of the highway construction, maintenance, street cleaning, and the collection and disposal of ashes, rubbish, and garbage, under the jurisdiction of the one organization. This would also have the added advantage of placing the street-cleaning work more generally on an engineering basis, which undoubtedly would lead to more sanitary methods of cleaning that would take into consideration the maintenance and care of the pavements themselves than is likely to be the case where the street cleaning is not under engineering supervision.



Plows to be used for the removal of snow.

2. *Character of Personnel.*—The head of the department should be a highway engineer with executive ability and versed in the principles of organization. These are the logical qualifi-

cations necessary to organize and operate such a department. Other than the clerical, stenographic, and audit and account divisions, in the higher grades of the supervising force the entire personnel should be engineers. In the lower grades, such as the inspection, they should be engineers or men with sufficient training in highway work to enable them to intelligently supervise the work coming under their jurisdiction.

The selection of the personnel is one of the most important and in many localities is becoming one of the most difficult problems, due to the methods employed by some of the Civil Service Commissions in determining the qualifications requisite for the selection of candidates for the higher engineering positions where personality, broad experience in controlling work, and good, sound business judgment should be the primary considerations. These qualifications are recognized to be essential for division heads in whom great responsibility is centred and on whom the success of the organization largely depends, and it is obvious that the selections in these cases should be left somewhat to the judgment of the head of the department, who is held responsible

Typical view of service test road which consists of twenty-six sections of different types of present-day standard materials and methods of construction.

for the work, rather than entirely to the judgment of a Civil Service Board, or through open competition in a technical examination. Civil Service was intended to safeguard the interests of the public and to do away with the "spoils" system, but the principle of Civil Service should be construed in a sufficiently broad manner to permit heads of departments to command control of the work, and this can only be done through a broad application of the Civil Service laws with regard to the selection of division heads in a large department. Considerable stress is laid on this point, as the responsibility of the planning and success of the organization or reorganization in a highway or any other department rests largely with the head of the department. In order to attain the best results his judgment must carry some weight in the selection of the division heads on whom he must rely, as, no matter how correct may be the planning of the organization to carry on and control the work, the ultimate success will depend largely upon the personality and judgment of these men.

Illustrating method of machine-broom cleaning.

The qualifications necessary to make a successful division head vary with the scope and character of work coming under the jurisdiction of the organization. Just because a man is a good highway engineer does not mean that he will be a success as a division head. Personality and business judgment carry just as much weight as engineering ability. The right type of man for such a position must not be lacking in imagination, and should possess the faculty of not only being a natural leader and commanding the respect of his subordinates, but he should also have their good will, and this means that he must establish a sort of *esprit de corps* in the organization. A man who operates through the good will of his subordinates accomplishes far more than the stern disciplinarian who lacks the good will and is feared by his subordinates. This is especially true in government, state, or municipal work, where the Civil Service laws and other considerations minimize the authority of the department heads.

Illustrating method of squeegee cleaning.

3. *Systematizing the Work.*—This requires a very careful study of all the activities of the department from the ground up, and their relation to one another, as the primary consideration should be to do away with as much unnecessary routine as is possible and still have an adequate system of control that embodies

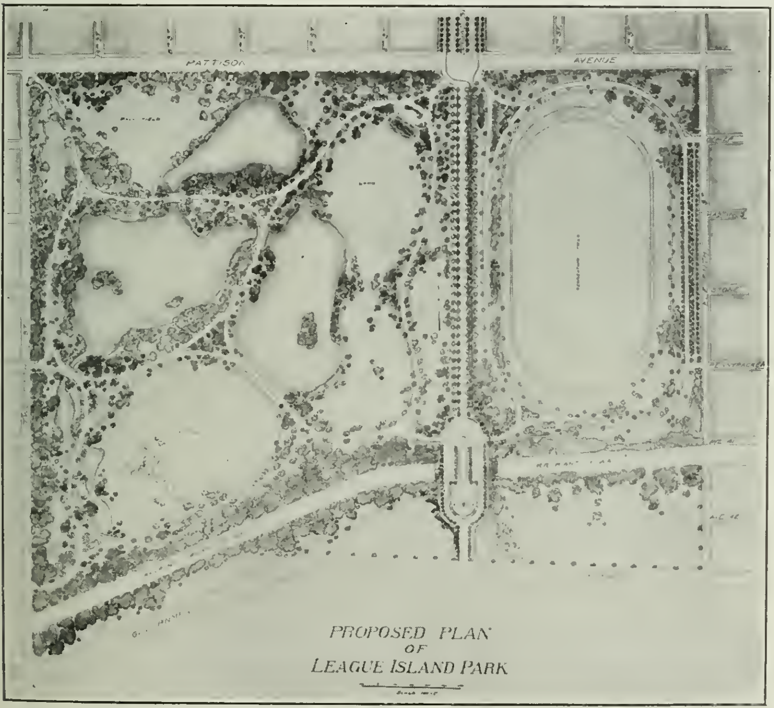
the compilation of all relevant data of value as a guide and a permanent record. Systematizing, of course, means simplifying the work, the bringing about of a maximum of efficiency with a minimum of energy, and in a highway department where the activities are so closely related that there is very apt to be an overlapping of jurisdiction and duplication of work it is obvious that a thorough systematizing of the work is essential.

METHOD OF OPERATION AND CONTROL.

Now, admitting that every department is more or less dependent upon a good organization, let us analyze briefly some of the conditions affecting the operation and control of a large municipal highway department. The greater part of the work coming under the jurisdiction of such a department, no matter how large or how small, is of a nature that involves so much detail that the real problem is one of maintenance. Therefore, the success from this standpoint is probably four-fifths dependent upon the organization. It is not intended to underestimate the necessity for a good organization to handle the construction, but this work is

Method of gang cleaning—following machine-broom and squeegee cleaning.

of a somewhat definite character and there are more or less well-defined principles that can be followed, both from the standpoint of the office and field, while the maintenance work coming under the jurisdiction of a modern highway department, which, we will assume, embraces all branches of work that is logically highway work, or the care and control of the highways from house line to house line, is an indefinite quantity and may be divided into three classes, namely:



1. Routine maintenance.
2. General maintenance.
3. Emergency maintenance.

For illustration we will consider only the more important functions under these classifications.

1. *Routine Maintenance.*—This includes the cleaning of streets, and this branch of work involves an enormous amount

of petty detail that is only definite in character in so far as the schedule of cleaning is concerned, which usually calls for a general cleaning for each particular street at regular intervals. The amount and character of cleaning, of course, is largely dependent upon the traffic, type of pavement, and density of population. Therefore, relatively speaking, from the standpoint of the state or county highway department, this problem is a comparatively simple one, consisting primarily of the cleaning of country roads, which work embraces scraping the shoulders and keeping the gutters open. The magnitude of this problem varies with the area to be covered and the density of population in a given area: from a more or less simple problem on a given country road it looms up into a very important one in a state highway department, and, likewise, from the cleaning of a given street in a small town it looms up into one of the most important problems in a large municipality; and both with regard to the state and municipal highway department it is largely a question of organization. Once the organization is perfected from an administrative standpoint, the work is two-thirds completed; and why?—simply because the work to be done is carried on under a more or less defi-

Improved granite block pavement in the vicinity of the West Philadelphia station of the Pennsylvania Railroad.

nite schedule. In a steel plant, so long as the machinery operates smoothly the output of the plant will be up to the standard. Likewise in a routine maintenance organization, such as street cleaning, so long as the organization operates smoothly the work will be properly done; but a poor organization will have the same effect upon the work as imperfect machinery would have upon the output of the steel plant. Therefore, the main problem in routine maintenance of this character is to organize a working force capable of performing the work along the lines of least resistance in an efficient and economical manner.

2. *General Maintenance.*—This includes street repairs which are of a distinctly variable quantity and, unlike routine maintenance, must be coped with by an organization of an entirely different kind from that for street cleaning, which organization consists of a regular working force employed all year round and of a more or less military character. The street repair work is usually divided into three classes:

Blockman with bag-carrier, broom, and pan.

1. Block pavement repairs.
2. Bituminous pavement repairs (mixing method), sheet asphalt, bituminous concrete, etc.
3. Country roads, macadam, gravel, etc., bituminous surface treatments, and earth road repairs.

These classifications involve different characters of work, each requiring special knowledge on the part of those engaged in the actual performance of the physical work. Stone block, wood block, and brick repairs, for example, require skilled laborers who have made a specialty of this work and are employed under the title of pavers and rammers, while repairs to asphalt and bituminous pavements must be performed by men specially trained in this line of work, in addition to the necessary force engaged at the mixing plants. Macadam road repairs, the care of earth roads, and bituminous surface treatments also require men specially skilled, and, while it is desirable to train the gangs for each particular branch of work under this classification, these subdivisions can be handled by those directly in charge of this division by training the laborers for the particular work to which they are assigned. It readily will be seen that this force, in the first place, can only be employed when the weather conditions are favorable for the work, which makes the organization much more difficult

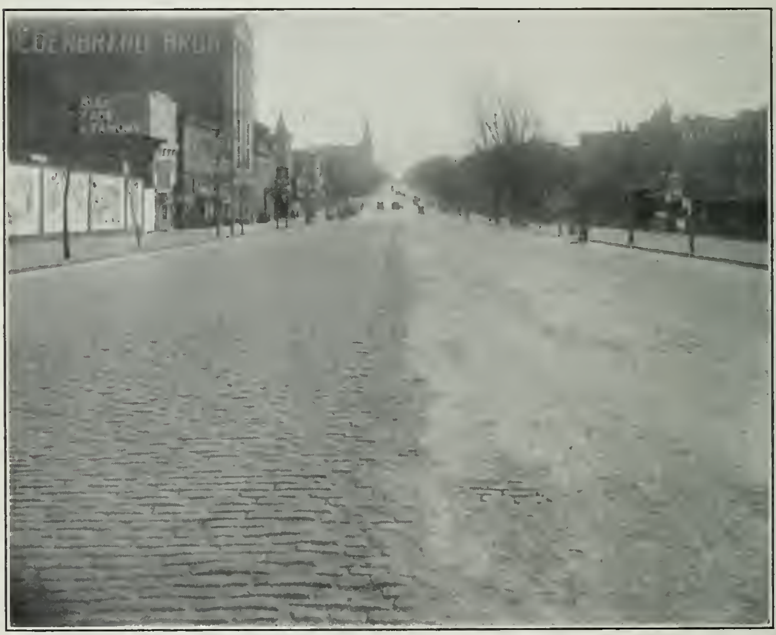
Typical view of the Northeast Boulevard, completed in 1914.

to control and keep up to a proper standard than one composed of men regularly employed all the year round. Moreover, the indefinite character of the work necessitates greater elasticity in the organization than does street cleaning, and makes it a still more perplexing organization to operate with success. In spite of this, the maintenance repairs to streets and roads is the most important branch of work coming under the jurisdiction of any highway department, and it will continue to be the most important, and this fact is becoming more recognized every day, and will be universally acknowledged when this work is placed strictly on an engineering basis throughout the country. Highway work, not only from a technical but from an organization standpoint, is distinctly an engineering problem, and so soon as this fact is more generally impressed upon the public and all the highway departments are put under the direction and control of engineers our highways will be properly constructed and maintained (in-

Typical view of modern brick pavement, cement grout joints.

stead of being used as a political bugaboo, as is the case in many localities to-day).

There is no definite schedule for a street repair maintenance organization to work on, and there are no fixed rules that can apply to all repair work other than that a "stitch in time saves nine," and when repairs are required they should be made at once. The materials to be used and the method and manner of making repairs are variable quantities for which only general principles can be set forth, which, of course, means that the organization coping with this work must be well trained and must respect and have confidence in their superiors, and every man, from the laborers to the chief engineer, should take a personal pride in the work. Ways and means of bringing this about is a real problem, and more so than in a routine maintenance organization where the work is of a more definite character; and why?



Illustrating the difference between the old granite block and same block split in half and relaid, giving a pavement practically as smooth as a new modern dressed granite block pavement.

—because work of an indefinite character opens up a channel for innumerable excuses, and, to be successfully coped with, requires a certain amount of initiative on the part of each and every man, from the laborers to the chief engineer, which makes their good will a necessary adjunct. The men should be taught to understand the relationship between their particular function and the work as a whole. This can be brought about through the installation of unit cost records, which, together with an educational campaign, consisting of meetings held at stated periods for the purpose of making clear the method of handling the work and each man's part in the work, will bring about a friendly rivalry between the different repair gangs. These meetings mean a great deal, as they set the men thinking, open up a new vision to them, and put them on their mettle, which will ultimately result in improving their opportunities.

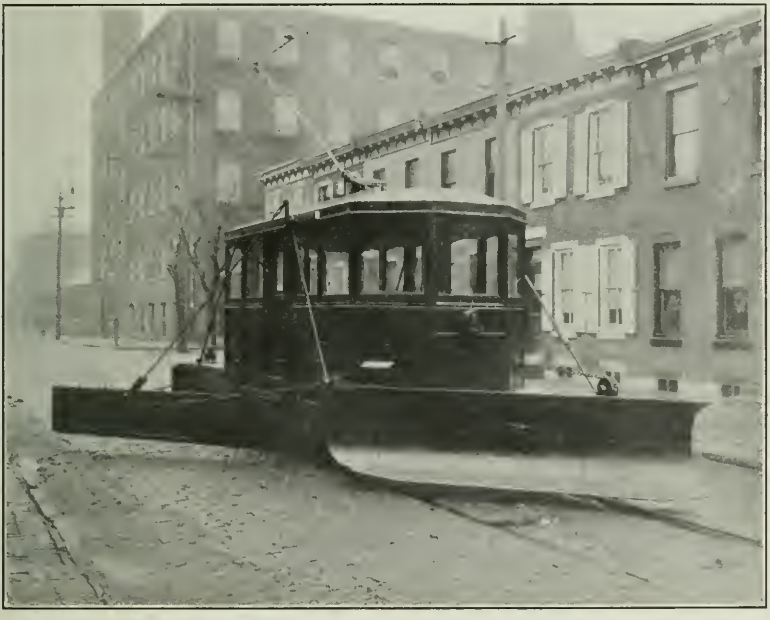
Typical asphalt construction with vitrified brick gutters.

3. *Emergency Maintenance.*—This includes snow removal, and it is unnecessary to dwell on the fact that, no matter what

appliances we may have for the removal of snow, the actual performance of the work is dependent upon the efficiency of a thorough and systematic planning of the operations, dividing and subdividing the city into sections covering areas of such a size that the work can be thoroughly and readily controlled by the supervising force. This work comes upon us so suddenly and must be performed in such a short space of time that it requires more supervision probably than any other branch of work, and it is for this reason that it can be better and more quickly handled by so dividing that each and every one controlling the work will be responsible for a certain definite area. This principle, of course, is true of any city, no matter how large or how small.

Typical view of modern wood block pavements in front of hospital.

The supervising force selected to control the work must be thoroughly instructed before the winter sets in, and imbued with a spirit of enthusiasm and pride in their part in the work. They must be available at all times, keep track of the weather conditions through the main office, where the latest weather reports should always be on file, and, so soon as the indications point to a storm, each and every one in the organization must set to work to get his equipment out on the street at the earliest possible moment. This necessitates his getting in touch with the contractor's teamsters, etc., and all the men assigned to his district, in order that they may start out immediately the snow shows signs of making any headway, which means, of course, so soon as it begins to cover the pavements. From that time on the whole organization must work day and night fighting the storm, which, after all, is the main problem. The appliances for the removal of the snow are secondary, as, no matter how well designed they may be for the purpose, the problem cannot be successfully coped with other than by fighting the storm, for it is obvious that to wait until it is over would unnecessarily tie up the traffic. Under a



Illustrating new plows to be used by the Philadelphia Rapid Transit Company. The adjustable wing will result in cleaning eight feet of the roadway in addition to the area of the track, thus opening up the street for traffic.

good organization, by using every possible means available for fighting the storm day and night, sufficient progress should be made to keep at least the main thoroughfares open for travel during and after the storm. There, of course, will be innumerable obstacles encountered that may seem beyond the control of those engaged in the work, but it is one of those problems that must be met by an organization imbued with a spirit that cannot be thwarted in accomplishing the result. This is simply the method that has been employed for a number of years by most of the railroad companies, while a great many of the cities have waited until the snow attained a considerable depth or ceased falling before they attempted to clean, which interferes with traffic and makes the work all the more difficult.

A snow fighting organization cannot be conducted along military lines, as it is evident that the work is of such a character that the success depends upon the determination and initiative of those charged with the supervision, and this can only be brought about through a spirit of coöperation, and every man connected with the supervising force must not only carry out the instructions of the head of the department, but use every means in his power to help the head of the department in coping with this problem.

These few illustrations of the difficulties encountered in the control of a large municipal highway department are self-evident and only accentuate the fact that the work must be thoroughly systematized and every possible means taken to control all the functions through a proper and definite procedure, supported by unit-cost records of each individual operation coming under the jurisdiction of the department. These records serve as a basis for determining upon future appropriations. They also serve as a means of control over the operations of the department, bringing out the strong and weak points in the organization and the economy and efficiency with which the work is being performed, both by comparing the different units of the organization with one another, and the different characters of work of the department with like work in other localities. A detailed outline of the procedure and explanation of the forms and unit-cost records required to control the work coming under the different functions would be voluminous to present here, but it is the intention to present them in detail for most of the work outlined in the 1914 report of the Bureau of Highways and Street Cleaning of the City of Philadelphia.

The following tables, however, are summaries of some of the records compiled for different classes of work, and will serve as illustrations of their importance, purely as a factor in the control of the organization and work. It will be noted that the city is divided into districts, and that the costs in these districts for the same class of work vary somewhat; some of this difference, particularly in street cleaning, is a result of the difficulty experienced in working on streets where the traffic is more congested than in other localities, but the difference in cost in many cases has brought out the strong and weak points of the organization. The records from which these data were compiled will also reveal like conditions in connection with the work of the smaller units of the organization, such as individual repair gangs, etc. (Of course, it must be considered that these tables represent the cost of work performed under an organization that has only recently undergone a complete reorganization, transformed from one with a supervising force of approximately 250 employees, whose yearly payroll was $260,000; that could boast of only one engineer at a salary of $1500 per year, and who was in a subordinate position, to one of which practically all the supervising force are engineers, and in the lower grades men with training in engineering work. This point has been brought out because the cost records are only intended to serve as an illustration of a means of control rather than as a basis for costs of the respective classes of work.)

A very important point, and one that has not been seriously considered in connection with highway engineering, is the relation of the cost of cleaning the different types of pavements to the cost of their maintenance during their economical life. In some instances, where the traffic is heavy and would ordinarily call for a heavy traffic pavement, it might be more economical to lay, for instance, a smooth pavement, such as sheet asphalt, taking into consideration the cost of cleaning.

According to Parsons, Freeman, and Herring's report in connection with their investigation of street cleaning in New York City, they state that the relative difference in cost of cleaning other pavements over and above sheet asphalt pavement per mile is:

Wood block (new)	$26.40
Asphalt block (average condition)	79.20
Brick pavement	105.60
Wood block (old)	132.60
Medina block	158.40
Granite block	211.20
Belgian block	264.00
Cobblestone	1,584.00

The present cost of the cleaning of the respective types of pavements in Philadelphia would indicate that for a 24-foot street it costs approximately $280 per year more to clean a granite block than an asphalt pavement per mile. Assuming, therefore, that on a 24-foot street a sheet asphalt pavement is laid at $2.25 per square yard (which price is probably a little high), it would cost $31,680 per mile. Assuming a life of ten years, the renewal for ten years for resurfacing would cost about $1.25 per square yard (which is also high), would cost $17,600, making a total for construction for twenty years of $49,280.

A granite block pavement of the same width, laid at $3.50 per square yard, would cost $49,280; add to this $5600, which is the difference in cost for cleaning the granite block over and above the asphalt, and subtracting the cost of the asphalt pavement ($49,280), makes a difference in cost for the granite block pavement, including the cost of cleaning, of $5600. This, of course, does not include interest and sinking fund charges, which would add still more to the cost of one granite block pavement over and above the cost of two sheet asphalt pavements for a term of twenty years. These figures are based on machine broom cleaning for granite block *versus* squeegee cleaning for sheet asphalt, and are simply rough calculations based on approximate costs, it being merely the intention to bring out the importance of adding the probable cost of cleaning to the calculated cost of maintenance repairs in making comparisons of the costs of construction and maintenance of the various types of pavement during their economical life. This opens up a field for investigation, as the cost of cleaning will surely be an important factor in the near future in connection with the selection of pavements.

To accentuate the importance and magnitude of the work of a large municipal highway department let us consider, for instance, the value of the pavements under the control of the Bureau of Highways and Street Cleaning in Philadelphia. The initial outlay, without renewals, represented in the 1587.21 miles of paved streets and roads in this city, exclusive of grading, is approximately $55,000,000. It would seem, therefore, that it is good business to maintain a proper engineering organization to protect this investment, which, together with the cost of the work coming under the jurisdiction of the bureau for the year 1914, totalling $7,855,206, gives an idea of the importance to a community of this function of the city government. The highway department is the principal showcase of a city government—the pavements representing the goods in the window—and it is good policy for any community, city, or state administration to keep them in first-class condition. The civic pride that has been aroused in the last few years throughout the country with reference to the highways in cities, states, and communities has resulted in increasing the importance of highway engineering and raising the standard of our roads and pavements in certain sections where this branch of work is being engineered (not as it is in many localities) by highway engineers. Each day the public is becoming more and more exacting, and any one who pauses for a moment to read the handwriting on the wall will agree that the inevitable outcome will be that this work throughout the entire country will soon be placed under the control of highway engineers.

The following is a tabulation in detail of the amount and character of contract work in force or on which bids were received during the year 1914, with the amounts thereof:

Character of work	Number of contracts	Amount
Paving	233	$1,278,240
Paving (private)	61	179,650
Repaving	56	340,309
Resurfacing (asphalt)	69	344,000
Resurfacing (vitrified block)	6	95,100
Resurfacing and surfacing macadam	87	705,690
Repairing and patching asphalt	1	250,000
Repairing and patching macadam	3	5,350
Curb and footway repairs (city to pay)	2	9,546
Curb and footway repairs (property owners to pay)	1	....
Constructing curb on Twenty-first Street	1	1,000
Grading	166	639,204
Parkway	4	5,890
League Island Park	1	490,000

Character of work	Number of contracts	Amount
Northeast Boulevard	2	$803,481
South Broad Street Boulevard	1	194,733
Sprinkling streets	3	25,000
Furnishing teams	7	52,000
Furnishing and operating dredge	1	2,531
Furnishing and delivering oil, sand, gravel, etc.	5	27,800
Furnishing and delivering stone	1	3,290
Collection and disposal of garbage	1	288,588
Cleaning streets	8	1,711,424
Disposal of waste and rubbish	2	......
Repairing and painting bridges	8	46,330
	730	$7,498,156

In addition to this contract work, work of a value of $357,048 was done by city forces in repairs to streets and roads, bridges and sewers, and meadow banks, bringing the total value of work under the direction of this bureau for the year 1914 up to $7,855,206.

DEPARTMENT OF PUBLIC WORKS
BUREAU OF HIGHWAYS AND STREET CLEANING.
Philadelphia, Pa.
Comparison of Street Cleaning Cost Data per 1,000 sq. yds.

District	MACHINE BROOM CLEANING		SQUEEGEE CLEANING		District
	Cost computed from		Cost computed from		
	Special test data	District daily reports	Special test data	District daily reports	
1–A	.202	.208	.146	.144	1–A
1–B	.220	.194	.118	.127	1–B
2	.262	.290	.101	.103	2
3	.233	.302	.205	.167	3
4–A	.253	.251	....	.225	4–A
4–B	.236	.226	.127	.202	4–B
5	.228	.336	.122	.129	5
6	.239	.232	.123	.176	6
Average unit cost	.232	.269	.134	.151	Average unit cost

The above does not include water.

Water at 0.04 per 1000 gallons = 0.004 (Mach. Broom), 0.010 (squeegee) per 1000 sq. yds.

The above costs include operating and direct supervision only and are based on the following:

Foremen	$2.50 per day.
Gangmen	1.75 per day.
2-horse sprinkler	5.00 per day.
Machine broom	5.50 per day.
Squeegee	6.00 per day.
Dirt cart	3.50 per day.
Dirt wagon	5.00 per day.

Street Pavements and Country Roads in the City of Philadelphia, December 31, 1913.

Character	Miles	Square yards
Granite block	348.32	6,573,246
Asphalt (sheet)	504.57	7,457,393
Asphalt (block)	7.39	69,950
Vitrified block	171.57	2,517,755
Wood block	8.16	186.848
Cobble	7.13	73,704
Rubble	4.63	65,213
Slag block	8.13	78,071
Cement and Granolitic	11.03	54,242
Total	1,070.93	17,076,422
Bituminous macadam roads	60.98	703,548
Waterbound macadam roads	242.10	2,799,488
Total macadam roads	303.08	3,503,036
Grand total (improved pavements and macadam roads)	1,374.01	20,579,458
Earth roads	213.2	....

DEPARTMENT OF PUBLIC WORKS—BUREAU OF HIGHWAYS.
UNIT COSTS FOR REPAIRS MADE BY CITY FORCES, 1914.
Resurfacing Waterbound Macadam.

District	Sq. yards	Labor	Teams	Material	Total	Average unit cost
1	9,021	1,620.66	1,121.00	2,805.90	5,547.56	.615
2	700	130.32	15.75	131.25	277.32	.396
3	......	....	....	....	....	....
4	......	....	....	....	....	....
5	10,075	1,136.64	1,682.00	2,299.73	5,118.37	.508
6	32,702	3,361.24	674.03	6,781.43	10,816.70	.331
7	55,951	3,994.05	3,704.75	11,743.11	19,441.91	.348
Total....	108,449	10,242.91	7,197.53	23,761.42	41,201.86	.38
7	3,378	123.21	105.25	106.99	335.45	.10
	Spiked up and rolled, very little material used.					

Patching Waterbound Macadam.

1	9,609	2,113.45	1,511.36	1,445.15	5,069.96	.528
2	.....	....	....	....	....	....
3	.....	....	....	....	....	....
4	.....	....	....	....	....	....
5	4,477	824.74	679.58	575.12	2,079.44	.464
6	14,357	1,701.42	599.89	1,419.09	3,720.40	.259
7	9,449	1,095.71	1,117.67	1,428.66	3,642.04	.385
Total....	37,892	5,735.32	3,908.50	4,868.02	14,511.84	.383

DEPARTMENT OF PUBLIC WORKS,

BUREAU OF HIGHWAYS AND STREET CLEANING,

Philadelphia, Pa.

Summary Showing Detail Costs of Bituminous Surface Treatment Work, Season 1914.

	Average per sq. yd.		Average labor cost per sq. yd.					Average material cost per sq. yd.			Aver. total cost per sq. yd.	Average total cost per sq. yd. First and second treat.	
	Gal. bit. mat.	Lbs. cov'g mat.	Sweeping		Chip'g	Clean up	Total labor	Bit. mat.	Cov'g mat.	Total mat.			
			Hand	Mach.								1914	1913
Refined coal tar, heavy (Tarvia A), first treatment	.464	16.2	.0051	.0017	.0046	.0026	.0140	.0373	.0175	.0548	.0688	.0641	.0824
Refined coal tar, heavy (Tarvia A), retreatment	.291	15.6	.0039	.0009	.0112	.0024	.0182	.0244	.0167	.0411	.0593		
Refined coal tar, light (Tarvia B), first treatment	.389	15.7	.0069	.0024	.0067	.0047	.0207	.0258	.0168	.0426	.0633	.0566	.0658
Refined coal tar, light (Tarvia B), retreatment	.314	14.6	.0044	.0011	.0055	.0034	.0144	.0200	.0155	.0355	.0433		
Refined water gas tar, light (Ugite), first treatment	.299	16.3	.0030	.0004	.0039	.0026	.0099	.0248	.0171	.0419	.0518	.0509	.0598
Refined water gas tar, light (Ugite), retreatment	.301	13.4	.0034	.0006	.0067	.0003	.0110	.0239	.0148	.0388	.0500		
Asphalt cutback, first treatment	.346	17.5	.0057	.0021	.0061	.0042	.0181	.0420	.0188	.0618	.0799	.0738	.0868
Asphalt cutback, retreatment	.297	18.5	.0026	.0014	.0057	.0039	.0136	.0309	.0223	.0532	.0677		

Gravel	Cost per 2000 pounds delivered on road	$2.14
Trap Rock Chips	Cost per 2000 pounds delivered on road, -1.749, 2.30 and 2.35—Average	2.30
Tarvia A per gallon applied—.08½	Ugite cold, per gallon, applied	.08
Tarvia B, per gallon, applied—.07	Ugite hot, per gallon, applied	.09
	Asphalt cut back, per gallon applied	.11⅔

All classes bituminous material	Total square yards treated	1,034,470
	Total gallons applied	334,377
	Total pounds covering material	14,435,347
	Total cost	$60,407.23

DEPARTMENT OF PUBLIC WORKS

BUREAU OF HIGHWAYS AND STREET CLEANING

Philadelphia, Pa.

Street Cleaning Cost Data—Machine Broom Work Per 1000 Square Yards

District	Computed from special test data																	From dist. daily reports	
	Granite block				Brick				Wood block				Asphalt				Average unit cost all classes	Average unit cost all classes	District
	Traffic			Unit cost	Traffic			Unit cost	Traffic			Unit cost	Traffic			Unit cost			
	Heavy	Med.	Light		Heavy	Med.	Light		Heavy	Med.	Light		Heavy	Med.	Light				
1–A	.337	.183	.200	.201	....	....	.208	.208	....	....	....	....	....	....	.198	.198	.202	.208	1–A
1–B	....	.237	....	.237	....	....	.218	.218	....	....	....	....	....	....	.147	.147	.220	.194	1–B
2	.290	.259	....	.281	....	.225	....	.225	....	.200	....	.200	....	.187	....	.187	.262	.290	2
3	.255	.220	....	.238	....	....	....	....	.217	....	....	.217	....	....	....	....	.233	.302	3
4–A	.282	.250	.200	.254	....	.226	....	.226	....	.264	....	.264	....	....	....	....	.253	.251	4–A
4–B	.283	.231	.209	.261	....	.221	....	.221	....	....	....	....	....	.243	.178	.186	.236	.226	4–B
5	.305	.227	.207	.250	....	.231	....	.231	....	....	....	....	....	.194	....	.194	.228	.336	5
6	....	.259	.233	.251	....	.277	.178	.210	....	....	....	....	....	....	....	....	.239	.232	6
Average unit cost				.245				.217				.217				.187	.232	.269	

The above does not include water—Water at 0.04 per 1000 gallons=0.004 per 1000 square yards.

The above includes the cost of the removal of the street dirt averaging 0.23 cubic yard per 1000 square yards. Cost of 0.087 per 1000 square yards.

The above costs include operating and direct supervision only and are based on the following:

Foremen, $2.50 per day
Gangmen, $1.75 per day
Machine Broom, $5.50 per day
Dirt Wagon, $5.00 per day
Dirt cart, $3.50 per day
Sprinkler, $5.00 per day

Table Showing Estimated Cost of Bituminous Treatment Work on Waterbound Macadam Roads for Philadelphia and Vicinity.

	Average per sq. yd.		Average labor cost per sq. yd.					Average material cost per sq. yd.			Av. total cost per sq. yd.
	Gal. bit. mat.	Lbs. cov'g mat.	Sweeping		Chip'g	Clean. up	Total labor	Bit. mat.	Cov'g mat.	Total mat.	
			Hand	Mach.							
Refined coal tar, heavy (Tarvia A), first treatment	.500	18	.0051	.0017	.0053	.0035	.0156	.0425	.0193	.0618	.0774
Asphalt cutback, first treatment	.500	18	.0051	.0017	.0053	.0035	.0156	.0583	.0207	.0790	.0946
Refined water gas tar, heavy (Ugite), first treatment	.500	18	.0051	.0017	.0053	.0035	.0156	.0450	.0207	.0657	.0813
Refined water gas tar, light (Ugite), first treatment	.500	16	.0051	.0017	.0053	.0035	.0156	.0400	.0193	.0593	.0749
Refined coal tar, light (Tarvia B), first treatment	.500	16	.0051	.0017	.0053	.0035	.0156	.0350	.0193	.0543	.0699
Refined coal tar, heavy (Tarvia A), second treatment	.333	15	.0036	.0010	.0045	.0025	.0116	.0283	.0161	.0444	.0560
Asphalt cutback, second treatment	.333	15	.0036	.0010	.0045	.0025	.0116	.0388	.0173	.0561	.0677
Refined water gas tar, heavy (Ugite), second treatment	.333	15	.0036	.0010	.0045	.0025	.0116	.0300	.0161	.0461	.0577
Refined water gas tar, light (Ugite), second treatment	.333	14	.0036	.0010	.0045	.0025	.0116	.0267	.0150	.0417	.0533
Refined coal tar, light (Tarvia B), second treatment	.333	14	.0036	.0010	.0045	.0025	.0116	.0233	.0150	.0303	.0499
Refined coal tar, heavy (Tarvia A), third treatment	.200	14	.0036	.0010	.0042	.0025	.0113	.0170	.0150	.0320	.0433
Asphalt cutback, third treatment	.200	14	.0036	.0010	.0042	.0025	.0113	.0236	.0161	.0397	.0510
Refined water gas tar, heavy (Ugite), third treatment	.200	14	.0036	.0010	.0042	.0025	.0113	.0180	.0150	.0330	.0443
Refined water gas tar, light (Ugite), third treatment	.200	13	.0036	.0010	.0042	.0025	.0113	.0160	.0139	.0299	.0412
Refined coal tar, light (Tarvia B), third treatment	.200	13	.0036	.0010	.0042	.0025	.0113	.0140	.0139	.0279	.0392

Based on the following labor and material costs

Tarvia A	.08½	per gallon applied on road
Tarvia B	.07	per gallon applied on road
Ugite hot	.09	per gallon applied on road
Ugite cold	.08	per gallon applied on road
Asphalt cut back	.11	per gallon applied on road
Gravel	2.14	per 2000 pounds delivered on road
Trap rock chips	2.30	per 2000 pounds delivered on road

Laborer	$2.00 per day
Foreman	$4.00 per day

All labor costs are based on the average labor costs of the Philadelphia Bituminous Surface Treatment work.

DEPARTMENT OF PUBLIC WORKS—BUREAU OF HIGHWAYS

UNIT COSTS FOR REPAIRS MADE BY CITY FORCES, 1914

Granite Block on Sand and Concrete Bases

District	Sq. yards	Labor	Teams	Material	Total	Average unit cost
1	32,989	8,781.65	927.20	1,144.32	10,853.17	.329
2	23,927	8,450.70	1,680.83	1,371.56	1,1503.09	.481
3	43,766	10,532.64	2,647.14	2,257.25	15,437.03	.353
4	50,541	14,632.08	1,494.40	2,865.20	19,991.68	.396
5	53,084	13,020.03	2,489.50	2,029.71	17,539.24	.33
6	23,214	6,774.36	1,158.24	245,66	8,178.26	.352
7	244	77.00	10.00	....	87.00	.357
Total......	227,765	62,268.46	11,407.31	9,913.70	83,589.47	.367
Vitrified Brick on Sand and Concrete Bases						
1	6,142	1,639.20	257.78	813.95	2,710.93	.441
2	3,271	1,100.90	244.23	502.13	1,847.26	.565
3	651	213.51	67.30	88.77	369.58	.568
4	2,094	586.19	193.81	584.87	1,364.87	.652
5	3,690	962.19	239.84	220.76	1,422.79	.386
6	23,206	5,803.77	1,093.82	624.31	7,521.90	.324
7	......	....	.. ..	....	....	....
Total......	39,054	10,305.76	2,096.78	2,834.79	15,237.33	.39
Asphalt						
On bituminous base:	4,480	2,330.72	490.77	167.20	2,988.69	.667
On concrete base:	2,470	1,301.76	237.20	72.30	1,611.26	.652

Automatic Signals on Victoria Bridge. R. F. MORKILL. (*Canad. Elec. News,* xxiii, 35.)—The paper describes the new alternating-current automatic signalling put into service by the Grand Trunk Railway across the Victoria Jubilee Bridge. The bridge is about 6600 feet in length, and has one electric and two steam roads. On account of heavy traffic the block sections have been made comparatively short, ranging from 2500 to 3600 feet. The signals are operated by single-phase, 110-volt, 60-cycle induction motors. Wireless control circuits are used with polyphase three-position relays, the local coils receiving energy at 12 volts from transformers on the track. Track transformers also supply energy for track circuits and signal lamps; all signals are lighted electrically by 2-candle-power, 2½-watt tungsten lamps. High- and low-tension wires are supported on a single cantilever cross-arm. On the bridge structure great difficulty was experienced in properly sighting the signals, but this was met by mounting the blade at the bottom of the spectacle casting.

Use of the Hering Furnace for Electric Brass Melting. G. CLAMER and C. HERING. (*Metallurgical and Chem. Eng.,* xii, 648.)—The Hering furnace is based on the use of the "pinch-effect" for heating and circulating the metal, and the author in this paper describes its application to brass melting. It is pointed out what a large amount of heat is carried out of the heating holes in the furnace bottom ("the resistors") effectively by the rapidly-flowing metal; it exceeds that of a row of electric arcs in these holes. At present about 25 to 50 kilowatts are converted into heat in each hole (or roughly about 90,000 to 200,000 B.T.U., equivalent to 20,000 to 45,000 kg.-cals. per hour), with the probability that this can be considerably increased. The correct proportioning of these holes and of the current is of great importance. These proportions are quite different for brass and for steel. The furnace must be especially designed for each metal, though variations in the composition of brasses and bronzes can be allowed for in the same furnace by regulation of the electric current. Even copper, with its very low resistance, can be melted commercially in these furnaces without requiring impracticable proportions. The higher the electrical resistivity of a metal the better the proportions become. The power factor of the furnace, even with 60 cycles, is not low, being 80 or 90 per cent.; the loss incurred is chiefly in the transformer, and should be avoided with a better design. In a steel furnace, with a frequency of 25, the power factor was practically 100 per cent. The Hering furnace has so far been used for melting very light brass and bronze chips, which gave trouble in the fuel furnaces. In melting many tons of these light, curly, and oily brass chips, with much mechanically mixed iron, they cast (in the form of clean ingots) nearly 8 pounds per kilowatt-hour delivered to the furnace transformers, equal to about 12.5 kilowatt-hours per 100 pounds poured. But there were various losses which can be avoided in the future. Short runs, with clean ingot charges, indicated that, even with the easily avoidable excesses in the losses, 10 pounds per kilowatt-hour could be obtained in this furnace—hence, in better designs, even still better efficiencies than this can reasonably be expected. But this figure depends largely on the amount of superheat required by the particular foundry man. The economy of the electric melting could be greatly increased by preheating the charge with a fuel flame, preferably in an auxiliary furnace, to only such a temperature at which no oxidation takes place. Comparisons are made between the operation costs of fuel-fired and electric furnaces for brass melting. Taking as an average 38 cents per 100 pounds for coke furnaces and 20 cents for the electric, the saving in a plant melting 20 tons per day would be nearly $22,000 per year of 300 days; or for oil furnaces at 43.2 cents and electric furnaces at 20 cents the saving would be nearly $28,000 per year, which should be credited to the first cost of the electric furnace.

IRON A FACTOR IN THE WORLD'S PROGRESS.*

BY

JOHN BIRKINBINE,

Consulting Engineer.
Member of the Institute.

The European war, while drawing heavily upon the resources affecting industries of contending nations, also seriously influences conditions in countries throughout the world not engaged in hostilities, threatening lasting effect and possible future changes in many phases of development. For this reason a discussion is offered of the relative positions of the leading countries which produce pig iron or supply the requisite raw materials for its manufacture, and to indicate past as well as present conditions a period of at least four decades has been chosen as covering practically the era of greatest industrial growth.

Prognostications as to future conditions are not attempted, but analyses of the data presented may suggest possibilities for nations now prominent or others wherein the development or utilization of the above commodities is less pronounced, while similar studies of other industrial specialties may indicate even greater changes.

Iron ore and coal hold leading rank among mineral resources whose development has been and is coincident with the world's progress, for countries possessing these abundantly, or utilizing them liberally, are the dominant nations.

The United States produces more coal, more iron ore, and more pig iron than any other nation, and her strongest competitors are the European countries now at war, for they are each an important factor in the supply of some or all of the above, and, together with the United States, are depended upon for

85 per cent. of the iron ore,
96 per cent. of the pig iron supply of the world,
89 per cent. of the coal.

They are also the most active producers of varied forms of iron and steel manufactures, a large proportion of their inhabitants being skilled and efficient in mine, furnace and mill work.

---

* Communicated by the Author.

A disturbance as momentous as that produced by the European conflict is far-reaching in its effect upon industrial progress, and its influence may be expected to continue long after peace is declared: for animosities do not cease with the suspension of active hostilities.

Consideration of iron as a factor in the world's progress necessarily is dependent on statistics, but, to relieve the discussion of voluminous tables, charts are presented on which are traced the conditions prevailing since 1870 in iron ore, coal, and pig iron productions of important nations. The quantities recorded are in long tons (2240 pounds), except for countries using the metric system, where the amounts are given in metric tons (2204 pounds).

Iron Ore.

Plate A illustrates the annual production of iron ores in the countries which have been or are prominent in supplying this mineral. The ordinates indicate in tons (the space between two longitudinal lines representing five million tons) the outputs of each country, designated by a particular form of line; the abscissæ show the years. By tracing the "curve" for any country, its production in a given year is found, or its contemporaneous position with other iron ore producing nations is demonstrated. Thus Plate A shows that Great Britain was the largest contributor of iron ore until 1889, when the United States took first place, and since 1895 Germany has exceeded the output of Great Britain. The contemporaneous contributions of the three nations were practically equal in the years 1893 and 1894, subsequent to which time the advance of Germany and of the United States has been more pronounced than that of Great Britain. In late years the iron ore output of France has materially advanced. It will be noted that the maximum annual productions of iron ore were, for the United States 1913, Great Britain 1882, Germany and Luxemburg 1913.[1] France 1912. Spain 1907, Russia 1911 (?), Sweden 1913, Austria-Hungary 1911 (?).[2]

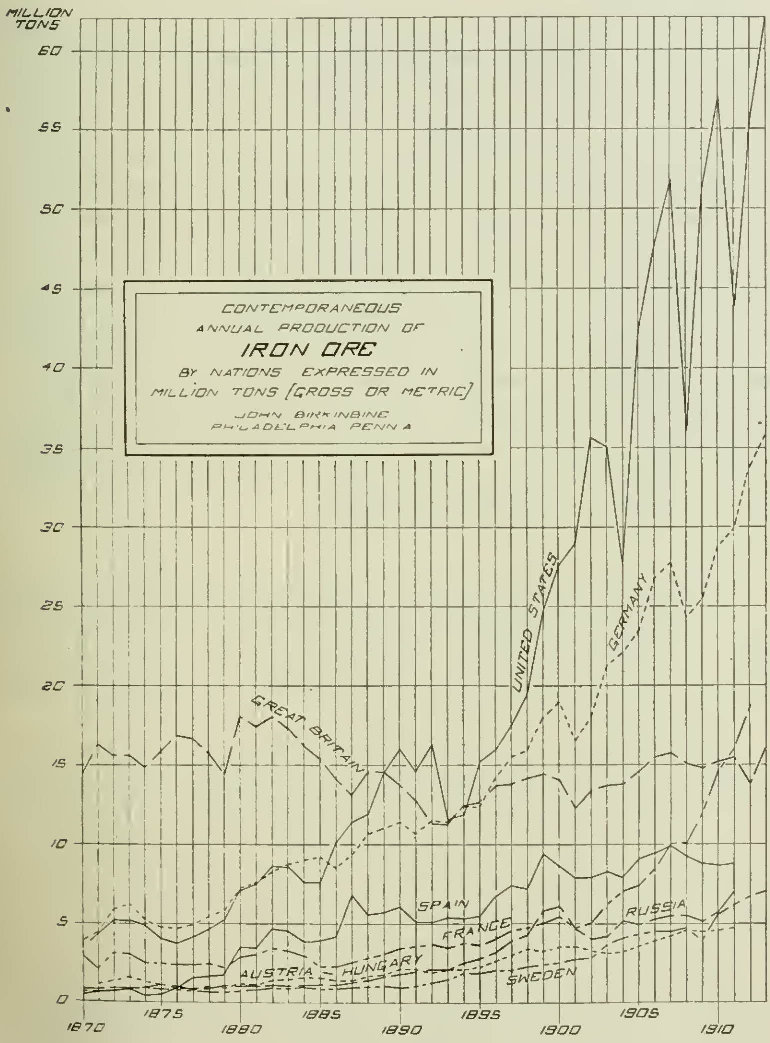
---

[1] The statistics of Luxemburg, which supplies liberal quantities of iron ore and coal, have been officially combined with those of Germany.

[2] (?) intimates that no authentic records are available subsequent to the date mentioned.

In addition to the countries designated in the graphic representation, the islands of Cuba and Newfoundland are each supplying about one and a half million tons of iron ore annually, and smaller amounts are mined in Canada, China, Greece, Italy, Algeria, Belgium, Tunis, Australia, India. Japan, Norway,

PLATE A.



Mexico, Brazil, Chile and Korea. Iron ore exists in minable quantities in most of the geographical divisions of the earth and in some of these there are known reserves of enormous extent and of excellent quality.

The majority of iron ores obtained in Spain, Sweden, Russia, and the United States average higher percentages of iron than those in Great Britain, Austria-Hungary, Germany and Luxemburg, France, and Belgium. Hence the relative weights of iron ore obtained in the different countries may not be considered as equitably comparative, for two tons of ore containing 60 per cent. iron will produce as much metal as three tons of 40 per cent. ore. The world's output of iron ore approximates 157,000,000 tons, the United States furnishing 36 per cent., and the nations now actively engaged in hostilities in Europe supplying an aggregate of 49 per cent. of the total iron ore product of the world. This resource is a most important factor, and it is asserted by some competent to judge that the control of the iron ore deposits of what was then eastern France and Luxemburg had a potential influence in the Franco-Prussian war of 1870, and is a factor in the present conflict.

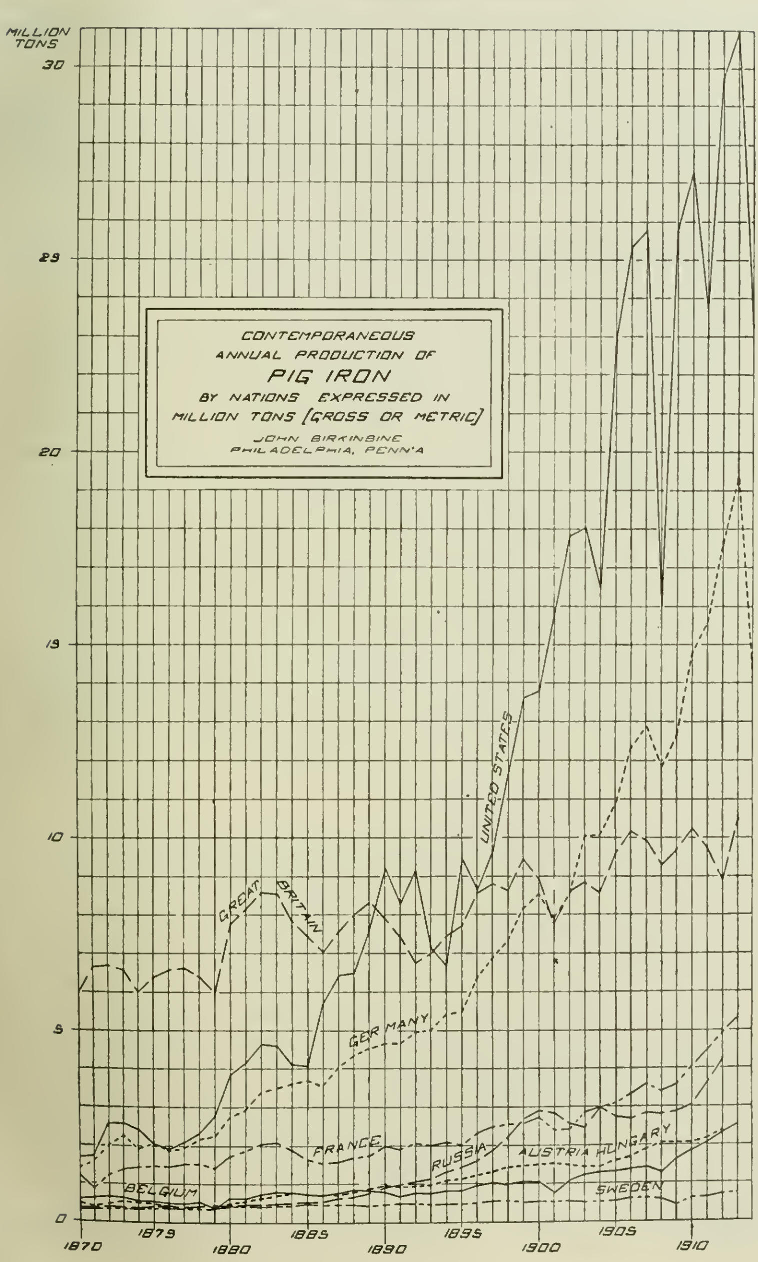
Pig Iron.

The graphic statement, Plate B, illustrates by ordinates, each space between horizontal lines representing 1,000,000 tons, the status of various countries as pig-iron producers subsequent to 1869, and indicates by " curves " the annual contribution of each nation in tons.

The diagram shows that England, which had long been preeminent in pig-iron manufacture, was outstripped by the United States in 1890, and that in 1903 Germany's product also exceeded that of Great Britain. Plate B, read in connection with Plate A, demonstrates that some important pig-iron producing countries depend to a greater or less extent upon other nations for iron ore, a feature which is later discussed.

Sweden, long celebrated for the excellence of its pig iron produced with charcoal as fuel, is included in Plate B, although its output is below, while those of all other nations shown on the diagram at present exceed 1,000,000 tons of pig iron annually. It will be noted that the maximum production of pig iron in each of the nations discussed was obtained within the past four years.

PLATE B.


CONTEMPORANEOUS
ANNUAL PRODUCTION OF
PIG IRON
BY NATIONS EXPRESSED IN
MILLION TONS (GROSS OR METRIC)
JOHN BIRKINBINE
PHILADELPHIA, PENN'A
MILLION TONS
30
25
20
15
10
5
0
1870
1875
1880
1885
1890
1895
1900
1905
1910
UNITED STATES
GREAT BRITAIN
GERMANY
FRANCE
RUSSIA
AUSTRIA HUNGARY
BELGIUM
SWEDEN

Among the countries supplying less than 1,000,000 tons of pig iron per year are: Canada (contributing over a half million tons), Spain, Italy, Japan, China, India, and Mexico.

The production of pig iron indicates that various commercial forms of iron and steel into which it enters are also locally fabricated. The employment of liquid metal from blast furnaces for steel conversion, and of continuous processes of manipulation used in the manufacture of merchantable metal, causes the district which produces pig iron to attain prominence in supplying various forms of iron and steel, thereby advancing it as an important industrial factor.

To obtain pig iron, ores, fuels, fluxes, and air are required; the last named is sufficiently abundant to cause no anxiety, and fluxes represent a minor part of the "charge." But the average ton of pig iron demands for its production the consumption of two tons of ore and a ton or more of satisfactory fuel. Hence the nation having its own supply of iron ore, and ample metallurgical fuel of desirable quality, has an advantage in the race for industrial supremacy. The total quantity of pig iron produced throughout the world is in the neighborhood of 73,000,000 tons. This is exclusive of metal obtained from forges by crude methods in a number of countries. Upon the above basis the United States at present supplies 41 per cent., and the combined output of the European nations in conflict is 55 per cent. of the world's pig-iron product.

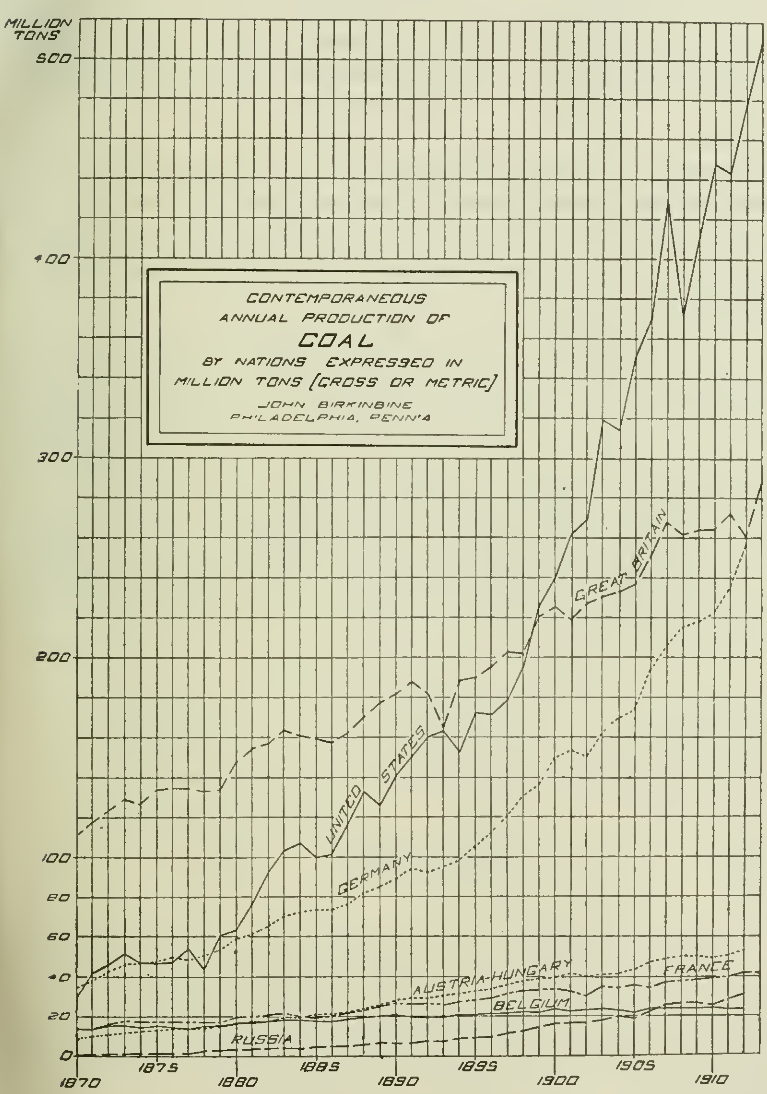
Coal.

Plate C, which follows the form of Plates A and B, except that the spaces between horizontal lines represent 20,000,000 tons, illustrates the production of coal by various nations, and when read in connection with Plates A and B shows how different countries compare in the production and utilization of coal and iron ore.

England maintained preëminence in coal output until 1898, but since that date the United States has been in the lead, and in 1913 produced almost as much coal as its nearest competitors, Great Britain, Germany and Luxemburg, combined. The United States supplies more coal than all of continental Europe; in fact, as much as the balance of the world excluding Great Britain—39 per cent.

The coal product of the United States and Great Britain averages higher grade than that of continental Europe, where large quantities of lignite or brown coal are secured, but the

PLATE C.



statistics given include the production of anthracite, bituminous, and lignite or brown coal.

In Plate C only those countries contributing 20,000,000 long or metric tons annually are indicated, but other countries mine large quantities of coal. Japan, China, India, and Canada each produces between 10,000,000 and 20,000,000 tons annually, and New South Wales, Spain, Transvaal, Natal, New Zealand, Mexico, Holland, and Chile each supplies between 1,000,000 and 10,000,000 tons yearly. About thirty countries produce smaller amounts.

In round numbers the total annual production of coal in the world at the present time is 1,250,000,000 tons, of which the United States contributes between 38 and 39 per cent., and the combined output of the European nations now at war approximates 50 per cent.

As supplementary to the three charts, the following statements are presented to show the position of each nation as a producer of iron ore, pig iron, and coal. To bring the statistics close to the present time, the obtainable records subsequent to the last census are given. The data are not completely contemporaneous, owing to the different periods for which information is available and to delays in making official statistics public.

The charts show that, according to latest official comparable data, the countries mentioned rank in volume of products in the following order:

Iron ore	Pig iron	Coal
United States,	United States,	United States,
Germany,	Germany,	Great Britain,
France,	Great Britain,	Germany,
Great Britain,	France,	Austria-Hungary,
Spain,	Russia,	France,
Sweden,	Austria-Hungary,	Russia,
Russia.	Belgium.	Belgium.

Analyses of these statements and of the three diagrams present some interesting, if not surprising, features.

The relative importance of the nations as producers of coal, iron ore, and pig iron is evident from the statistics presented, but the population of the countries and the relation which this bears to the quantities produced are of interest.

Thus, in per capita production, the nations rank:

As producers of iron ore	As producers of pig iron	As producers of coal
Sweden,	United States,	Great Britain,
United States,	Belgium,	United States,
Germany,	Germany,	Germany,
France,	Great Britain,	Belgium,
Great Britain,	France,	France,
Austria-Hungary,	Sweden,	Austria-Hungary,
Russia	Austria-Hungary,	Japan,
	Russia.	Russia.

Progress in iron ore and coal mining, and in the manufacture of pig iron, between the years 1870 and 1910, shows as follows for the various countries, the quantities being quoted as per 1000 inhabitants:

In the interval of forty years the population of the United States increased from 38,500,000 to 92,000,000; its coal output rose from 765 to 4869 tons; its iron ores mined from 100 to 620 tons, and its pig iron made from 43 to 297 tons per 1000 inhabitants, the rate of increase being most pronounced in the last twenty years.

In the same period Great Britain's population advanced from 32,000,000 to 45,000,000, and its coal output increased from 3685 to 5994 tons, but its iron ore production decreased from 513 to 342 tons (in the decade ending 1901 to 292 tons). The amount of pig iron manufactured rose from 208 to 214 tons per 1000 inhabitants, reaching 231 tons in 1881.

In Germany and Luxemburg the population was augmented from 41,000,000 in 1871 to 66,000,000 in 1910; its coal output advanced from 922 to 3360 tons, its iron ore production from 106 to 434 tons, and the pig iron manufactured from 38 to 224 tons per 1000 inhabitants.

In forty years the population of France advanced from 36,000,000 to 39,600,000, and contemporaneously its proportionate coal production grew from 438 to 991 tons, its iron ore output from 85 to 404 tons, and pig iron manufactured from 34 to 113 tons per 1000 inhabitants.

In Austria-Hungary the increase in population was from 36,000,000 in 1870 to 49,000,000 in 1910. In the same interval its coal output was augmented from 233 to 989 tons, its iron ore product from 32 to 92 tons, and the amount of pig iron manufactured from 13 to 41 tons per 1000 inhabitants.

From 1870 to 1912 the population of Russia has risen from

85,000,000 to 171,000,000, and in that interval its coal mined advanced from 8 to 179 tons, its iron ore output from 9 to 41 tons, and its pig iron manufactured from 4 to 24 tons per 1000 inhabitants.

Belgium produces but little iron ore, but, while its population advanced from 5,000,000 in 1870 to 7,500,000 in 1910, its proportionate coal output rose from 2692 to 3222 tons, reaching 3505 tons in the year 1900. This nation is a liberal manufacturer of pig iron, of which it produced 111 tons in 1870 and 249 tons in 1910 per 1000 of population.

Sweden differs from Belgium in having but a small coal supply but an abundance of iron ore. In the forty years the population advanced from 4,000,000 to 5,500,000, its iron ore output, much of which is exported, rose from 151 to 1006 tons, and its pig-iron production using charcoal as fuel from 72 to 109 tons per 1000 inhabitants.

To illustrate the position of various nations as producers of coal, iron ore and pig iron, a series of statistical statements has been prepared covering the interval from 1870 to the present time, divided by decades. These show for each nation the total production in a decade, also the mean, maximum and minimum annual productions.

Reference has been made to the interdependence of nations, and, without attempting detailed explanation, this is epitomized in statements from latest data available of the amounts of iron ore, coal and pig iron exported and imported by various countries.

In the *United States* all iron ore produced, except about 1,000,000 tons annually exported to Canada, is smelted in the country, and in addition, in late years, from 2,000,000 to 2,600,000 tons of iron ore are imported, principally from Cuba, Sweden, and Newfoundland.

The imports of pig iron and ferro alloys in late years into the United States range from 130,000 to 237,000 tons and the exports from 60,000 to 275,000 tons, showing that the domestic pig iron is used at home.

From 12,000,000 to 22,000,000 tons of coal are annually exported from and 1,250,000 to 2,000,000 tons imported into the United States.

Germany and Luxemburg smelt their domestic iron ores, and in addition import 11,000,000 to 14,000,000 tons, principally from Sweden, France, and Spain, and have exported about 2,500,000 tons, chiefly to Belgium and to France.

Germany annually imports 125,000 to 140,000 tons, and exports in the neighborhood of 1,000,000 tons of pig iron.

Thirty-one million to thirty-four million five hundred thousand tons of German coal are exported to Austria-Hungary, Holland, Belgium, France, Sweden, and Russia, and from 17,500,000 to 18,500,000 tons are imported into Germany.

Great Britain, in addition to its domestic iron ore supply, draws 6,000,000 to nearly 8,000,000 tons from foreign mines, two-thirds coming from Spain, although Algeria, Norway, Sweden, Tunis, Greece, and France contribute considerable quantities. No ore is exported.

Great Britain exports from 1,000,000 to 2,000,000 tons of pig iron, but the imports seldom exceed 250,000 tons.

Of its large fuel production, 65,000,000 tons of coal and about 1,000,000 tons of coke are exported to continental European, South American, and other countries. Those receiving more than 5,000,000 tons of British fuel annually are France, Italy, Germany, Sweden, and Norway.

France.—Four million to over eight million tons of French iron ore are annually exported, principally to Belgium and Germany, and from 1,000,000 to 2,000,000 tons of iron ore are imported, mostly from Germany and Spain. France exported from 100,000 to 250,000 tons of pig iron annually, while its imports of this metal are less than half these amounts.

France imports (mostly from England) about 16,000,000 tons of coal and 2,000,000 to 2,750,000 tons of coke, while its fuel exports are from 1,300,000 to 2,000,000 tons.

Russia exports little iron ore, but about 4,000,000 tons of coal and 500,000 or more tons of coke are imported.

Austria-Hungary imports annually from 500,000 to 600,000 tons of iron ore, mainly from Sweden, and exports about 100,000 tons, principally to Germany. From 100,000 to 200,000 tons of pig iron are imported and 28,000 to 60,000 tons exported.

From 9,000,000 to 12,000,000 tons of coal are imported, principally from Germany, and 8,000,000 tons, mostly lignite, are exported chiefly to Germany.

Spain is a large iron ore producer, and exports 7,000,000 to 9,000,000 tons per year, the greater portion going to Great

Britain. It produces 300,000 to 400,000 tons of pig iron, and its imports and exports are small. The domestic production of coal is augmented by importations of 2,000,000 tons annually.

Belgium mines from 125,000 to 250,000 tons of iron ore annually, but imports mostly from France, Germany, and Spain 5,000,000 to 6,000,000 tons, about 500,000 tons of which are reëxported to Germany.

Belgium fabricates practically all of its pig-iron product, and also imports about two-thirds of a million tons annually, the larger part from Germany, although Great Britain and France also furnish pig iron. It mines from 22,000,000 to 24,000,000 tons of coal, imports 6,000,000 to 7,500,000 tons, and exports about 5,000,000 tons, principally to France.

Sweden produces an abundance of high-grade iron ore, the greater part of which is exported to Germany, England, Belgium, and the United States. The pig-iron industry depends almost entirely on charcoal, about one-fourth of the production being exported.

The various nations have been discussed independently of any colonies or dependencies, for, as before stated, the pig iron made has not been followed through mills and factories. But the statements presented may indicate how intimate the association has been between nations now combating each other and seeking to cripple their adversaries in every possible manner. These may also suggest the present and prospective status of each country as a contributor to the supply of resources necessary for the world's advancement, and show how changes of boundary lines may enlarge or reduce the independent manufacturing possibilities of the nations now at war.

On preceding pages reference has been made to the necessary interchange of the raw or the manufactured materials between the countries now at conflict, and it is possible that the result of the war may greatly strengthen some or seriously cripple others of the contestants, according to the peace terms which may be agreed upon. The commercial supremacy of each nation is, to a great extent, controlled by its ability to manufacture articles of iron and steel.

The effects of such changes may extend far beyond the limits of the countries contending with each other, and the possession of natural reserves of some nations or colonies and also in the Orient may be more than a mere incident in the European War.

PRODUCTION OF IRON ORE in the Eight Principal Iron-Ore Mining Countries in the World, from 1870 to 1913, by Ten-year Periods.

UNITED STATES—Long Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 1879	44,645,440	4,464,544	1879	5,255,000	1876	3,734,000
1880 1889	95,089,403	9,508,940	1889	14,518,041	1880	7,120,362
1890 1899	163,989,193	16,398,919	1899	24,683,173	1893	11,587,629
1900 1909	383,932,500	38,393,250	1907	51,720,619	1900	27,553,161
1910 1913	218,022,042	54,505,510	1913	61,980,437	1911	43,876,552

GERMANY AND LUXEMBURG—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 1879	51,160,842	5,116,084	1873	6,177,576	1870	3,839,222
1880 1889	89,499,306	8,949,931	1889	11,002,187	1880	7,238,640
1890 1899	133,313,059	13,331,306	1899	17,989,635	1891	10,657,521
1900 1909	224,434,495	22,443,450	1907	27,697,127	1901	16,570,182
1910 1913	128,284,212	32,071,053	1913	35,941,285	1910	28,729,700

GREAT BRITAIN—Long Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 1879	156,173,886	15,617,389	1876	16,841,584	1870	14,370,655
1880 1889	158,823,859	15,882,386	1882	18,031,957	1887	13,098,041
1890 1899	130,184,239	13,018,424	1899	14,461,330	1893	11,203,476
1900 1909	142,877,457	14,287,746	1907	15,731,604	1901	12,275,198
1910 1913	60,533,158	15,133,290	1913	15,997,328	1912	13,790,391

FRANCE—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 1879	25,715,612	2,571,561	1872	3,081,026	1871	2,099,706
1880 1889	28,743,748	2,874,375	1882	3,467,251	1886	2,285,648
1890 1899	40,088,780	4,008,878	1899	4,985,702	1890	3,471,718
1900 1909	76,317,045	7,631,705	1909	11,890,000	1902	5,003,782
1910 1912	49,410,078	16,470,026	1912	18,800,000	1910	14,605,542

PRODUCTION OF IRON ORE in the Eight Principal Iron-Ore Mining Countries in the World, from 1870 to 1913, by Ten-year Periods.—Continued.

Spain—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 1879 ..	9,419,302	941,930	1874	423,401	1877	1,578,150
1880 1889 ..	46,444,883	4,644,488	1887	6,796,266	1881	3,502,681
1890 1899 ..	63,292,106	6,329,211	1899	9,397,733	1892	5,041,317
1900 1909 ..	87,235,290	8,723,529	1907	9,896,178	1902	7,904,555
1910 1911 ..	17,440,486	8,720,243	1911	8,773,691	1910	8,666,795

Russian Empire—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 1879 ..	9,166,008	916,601	1875	1,056,545	1871	794,779
1880 1889 ..	11,692,556	1,169,256	1889	1,646,840	1883	998,393
1890 1899 ..	30,468,011	3,046,801	1899	5,788,709	1890	1,802,165
1900 1909 ..	50,621,536	5,062,154	1900	6,122,270	1902	4,004,007
1910 1911 ..	12,750,218	6,375,109	1911	6,985,039	1910	5,765,179

Sweden—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 1879 ..	7,466,982	746,698	1874	926,825	1870	630,739
1880 1889 ..	8,883,492	888,349	1889	985,904	1880	775,344
1890 1899 ..	17,402,164	1,740,216	1899	2,435,200	1890	941,241
1900 1909 ..	38,011,618	3,801,162	1908	4,713,160	1900	2,609,500
1910 1913 ..	25,886,414	6,471,604	1913	7,479,393	1910	5,552,678

Austria-Hungary—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1871 1879 ..	10,246,331	1,138,481	1873	1,588,058	1877	884,260
1880 1889 ..	14,632,594	1,463,259	1889	1,780,772	1881	1,084,443
1890 1899 ..	25,162,976	2,516,298	1899	3,293,004	1892	1,913,831
1900 1909 ..	37,511,679	3,751,168	1908	4,568,814	1903	3,155,116
1910 1911 ..	9,245,998	4,622,999	1911	4,712,666	1910	4,533,332

PRODUCTION OF PIG IRON in the Eight Principal Pig-iron Producing Countries in the World, from 1870 to 1914, by Ten-year Periods.

UNITED STATES—Long Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 1879 ..	21,885,266	2,188,527	1879	2,741,853	1870	1,665,179
1880 1889 ..	51,534,529	5,153,453	1889	7,603,642	1880	3,835,191
1890 1899 ..	93,538,215	9,353,822	1899	13,620,703	1894	6,657,388
1900 1909 ..	197,807,609	19,780,761	1909	25,795,471	1900	13,789,242
1910 1914 ..	134,978,776	26,995,755	1913	30,966,301	1914	23,332,244

GERMANY AND LUXEMBURG—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 1879 ..	19,272,726	1,927,273	1873	2,240,575	1870	1,391,124
1880 1889 ..	36,195,906	3,619,591	1889	4,524,558	1880	2,729,038
1890 1899 ..	58,777,609	5,877,761	1899	8,143,132	1891	4,641,217
1900 1909 ..	105,500,005	10,550,001	1907	12,875,159	1901	7,880,087
1910 1914 ..	81,683,742	16,336,748	1913	19,309,172	1914	14,389,547

GREAT BRITAIN—Long Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 1879 ..	63,796,993	6,379,699	1872	6,741,929	1870	5,963,515
1880 1889 ..	79,127,923	7,912,792	1882	8,586,680	1886	7,009,754
1890 1899 ..	79,614,624	7,961,462	1899	9,421,435	1892	6,709,255
1900 1909 ..	91,251,065	9,125,107	1906	10,149,388	1901	7,761,832
1910 1913 ..	39,306,601	9,826,650	1913	10,481,917	1912	8,889,124

FRANCE—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 1879 ..	13,364,987	1,336,499	1878	1,521,274	1871	859,641
1880 1889 ..	17,723,834	1,772,383	1883	2,069,430	1886	1,516,574
1890 1899 ..	21,919,062	2,191,906	1899	2,567,388	1891	1,897,387
1900 1909 ..	30,278,382	3,027,838	1907	3,590,235	1901	2,388,823
1910 1913 ..	18,758,948	4,689,737	1913	5,311,316	1910	4,038,297

PRODUCTION OF PIG IRON in the Eight Principal Pig-iron Producing Countries in the World, from 1870 to 1914, by Ten-year Periods.—Continued.

RUSSIA—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 1879 ..	3,805,983	380,598	1879	420,660	1871	339,513
1880 1889 ..	5,278,717	527,872	1889	733,720	1880	427,696
1890 1899 ..	15,113,846	1,511,385	1899	2,677,120	1890	905,460
1900 1901 ..	27,634,376	2,763,438	1904	2,962,283	1903	2,449,701
1910 1912 ..	10,830,846	3,610,282	1912	4,197,635	1910	3,040,047

AUSTRIA-HUNGARY—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 1879 ..	4,423,447	442,345	1873	534,508	1877	387,630
1880 1889 ..	6,838,158	683,816	1889	855,822	1880	464,234
1890 1899 ..	11,431,258	1,143,126	1899	1,467,664	1891	921,846
1900 1909 ..	16,119,729	1,611,973	1909	1,995,511	1904	1,375,865
1910 1912 ..	6,545,212	2,181,737	1912	2,372,660	1910	2,060,975

BELGIUM—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 1879 ..	5,379,203	537,920	1872	655,565	1879	389,330
1880 1889 ..	7,323,421	732,342	1889	832,226	1880	608,084
1890 1899 ..	8,631,404	863,140	1899	1,036,185	1891	684,126
1900 1909 ..	12,335,766	1,233,577	1909	1,616,370	1901	764,180
1910 1913 ..	8,726,830	2,181,708	1913	2,527,070	1910	1,852,090

SWEDEN—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 1879 ..	3,343,027	334,303	1876	352,467	1871	298,761
1880 1889 ..	4,329,398	432,940	1885	464,737	1882	398,945
1890 1899 ..	4,873,948	487,395	1897	538,197	1893	453,421
1900 1909 ..	5,401,295	540,130	1907	615,778	1909	444,764
1910 1913 ..	2,668,404	667,101	1913	730,257	1910	603,939

PRODUCTION OF COAL in the Eight Principal Coal-Mining Countries in the World, from 1870 to 1913, by Ten-year Periods.

UNITED STATES—Long Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 1879	476,566,017	47,656,602	1879	60,808,749	1870	29,496,054
1880 1889	1,019,753,264	101,975,326	1888	132,701,827	1880	63,822,830
1890 1899	1,712,331,738	171,233,174	1899	226,554,635	1890	140,866,931
1900 1909	3,337,185,589	333,718,559	1907	428,895,914	1900	240,789,310
1910 1913	1,877,082,366	469,270,592	1913	508,971,540	1911	443,054,614

GREAT BRITAIN—Long Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 1879	1,274,494,850	127,449,485	1877	134,179,968	1870	110,431,192
1880 1889	1,607,990,447	160,799,045	1889	176,916,724	1880	146,969,409
1890 1899	1,910,785,455	191,078,546	1899	220,094,781	1893	164,325,795
1900 1909	2,414,416,661	241,441,666	1907	267,830,962	1901	219,046,945
1910 1913	1,084,171,738	271,042,935	1913	287,430,473	1912	260,416,338

GERMANY—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 1879	456,561,932	45,656,193	1879	53,470,716	1870	34,003,004
1880 1889	719,117,229	71,911,723	1889	84,973,230	1880	59,118,035
1890 1899	1,073,735,837	107,373,584	1899	135,824,427	1890	89,051,527
1900 1909	1,791,128,249	179,112,825	1909	217,445,656	1900	149,788,256
1910 1912	711,706,424	237,235,475	1912	255,810,094	1910	222,375,076

FRANCE—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 1879	161,713,709	16,171,371	1873	17,479,341	1871	13,258,920
1880 1889	208,703,065	20,870,307	1889	24,303,509	1881	19,361,564
1890 1899	286,581,124	28,658,112	1899	32,863,000	1893	25,650,981
1900 1909	346,903,640	34,690,364	1909	37,840,086	1902	29,997,470
1910 1913	159,716,914	39,929,229	1912	41,145,178	1910	38,349,942

PRODUCTION OF COAL in the Eight Principal Coal-Mining Countries in the World, from 1870 to 1913 by 10-year periods.

AUSTRIA-HUNGARY—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 1879	121,822,412	12,182,241	1879	14,891,024	1870	8,355,944
1880 1889	202,430,110	20,243,011	1889	25,328,417	1880	16,128,718
1890 1899	325,647,572	32,564,757	1899	38,739,000	1890	27,504,032
1900 1909	439,719,257	43,971,926	1908	49,626,184	1900	39,502,301
1910 1912	151,031,218	50,343,739	1912	52,521,776	1910	48,649,768

RUSSIA—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 1879	15,555,667	1,555,567	1879	2,874,790	1870	696,673
1880 1889	43,237,790	4,323,779	1889	6,213,869	1880	3,286,534
1890 1899	91,966,854	9,196,685	1899	14,311,200	1890	6,085,080
1900 1909	204,227,251	20,422,725	1909	26,075,086	1900	16,135,600
1910 1912	83,551,747	27,850,582	1912	30,646,163	1910	24,898,345

BELGIUM—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1870 1879	146,893,125	14,689,313	1873	15,778,401	1877	13,669,077
1880 1889	179,771,122	17,977,112	1889	19,869,980	1881	16,873,951
1890 1899	206,800,233	20,680,023	1898	22,075,093	1893	19,410,519
1900 1909	231,237,587	23,123,759	1907	23,705,190	1905	21,775,280
1910 1912	69,942,240	23,314,060	1910	23,916,560	1912	22,972,140

JAPAN—Metric Tons.

Period	Total production	Mean annual production	Year	Maximum	Year	Minimum
1881 1889	12,808,235	1,423,136	1889	2,388,614	1881	925,198
1890 1899	45,721,857	4,572,186	1898	6,761,301	1890	2,608,284
1900 1909	115,283,197	11,528,320	1909	14,973,617	1900	7,429,457
1910 1912	52,953,789	17,651,263	1912	19,639,755	1910	15,681,324

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

THE SPECIFIC HEAT AND HEAT OF FUSION OF ICE.

By H. C. Dickinson and N. S. Osborne.

RESULTS of previous determinations of the specific heat of ice by certain observers have indicated a rapid increase in the specific heat on approaching the melting-point; whereas A. W. Smith[†] has found the heat capacity of ice to be practically constant up to temperatures very close to zero, provided great care and refinement are used to insure the purity of the ice, and that sensible increase in the apparent heat capacity with ice samples of only ordinary purity are accounted for by the assumption of incipient fusion caused by the lowering of the melting-point by the dissolved impurities.

The present investigation has been undertaken with the object of securing further evidence as to the thermal behavior of ice at temperatures near the freezing-point, and of obtaining reliable data for the construction of tables of total heat of ice and water in the range of temperature with which refrigerating engineers are concerned.

The measurements were made by means of a calorimeter of aneroid type (*i.e.*, without stirred liquid as calorimetric medium), which is described in detail in a separate paper.

Briefly described, the tin-lined metal cell containing the specimen is enclosed within a shell of copper, the copper acting as the calorimetric medium for transmission and distribution of heat electrically developed in a coil built into the shell. The calorimeter is surrounded by air and enclosed in a metal jacket which is surrounded by a stirred liquid bath, the temperature of which can be controlled within a few thousandths of a degree at any temperature between − 55° and + 40° C. Measured amounts of heat are supplied to the calorimeter electrically by means of the built-in heating coil. The calorimeter temperature is measured by means of a platinum resistance thermometer also built into the shell. Differences in temperature between the calorimeter and jacket surfaces are measured by means of multiple thermocouples distributed on the surfaces. During an experiment thermal leakage is minimized by keeping the temperature of the jacket nearly equal to the changing temperature of the calorimeter.

---

* Communicated by the Bureau.

[†] *Physical Review,* 17 (1903), p. 193.

The samples used were from 400 to 470 grammes each. Three samples were of redistilled water of fairly high purity, while a fourth, which was distilled directly into the container, appeared, from the experimental results, to have a much higher degree of purity.

In the determinations of specific heat it is found that over the range of temperature covered by the experiments (*i.e.*, $-40°$ to $-0.05°$ C.) the specific heat S, in 20° calories at any temperature θ, of the four ice samples is represented within the limit of experimental error by the equation:

$$S=0.5057+0.001863\theta-79.75\,\frac{l}{\theta^2}$$

in which the constant l is assumed to represent the the initial freezing-point of the specimen and has the following values:

Sample	l
1	-0.00125
2	.00120
3	.00095
4	.00005

From the fact that the term which represents the departure of the specific heat from a linear function of the temperature is found to depend on the purity, being less the purer the ice, it is concluded that the specific heat of pure ice in 20° calories may be closely represented by the equation:

$$S = 0.5057 + 0.001863\theta$$

Determinations of the heat of fusion made upon three of the samples used for the specific heat determinations gave the following values:

Sample number	Heat of fusion, Cal $_{20}$/g
1	79.68
2	79.85
4	79.75
Mean	79.76

The results of a previous investigation at the Bureau of Standards using very different methods to determine the heat of fusion of ice give, when corrected for the newly-found value for specific heat, a mean value of 79.74 20° calories per gramme.

The mean for the two investigations is 79.75 20° calories per gramme.

For the use of engineers a table of total heats of ice and water is given expressed in B. T. U.'s per pound at temperatures from – 20° F. to + 100° F.

TABLE 12.

Table of Total Heat of Ice and Water.

Temperature of ice t deg. F.	Difference in total heat per pound from ice at t to		Temperature of water t' deg. F.	Difference in total heat per pound from water at 32° to water at t' $h_{t'}-h_{32}$ B.T.U./lb.
	Ice at 32° $H_{32}-H_t$ B.T.U./lb.	Water at 32° $h_{32}-H_t$ B.T.U./lb.		
−20	23.8	167.2	+32	0.0
−18	22.9	166.3	34	2.0
−16	22.1	165.5	36	4.0
−14	21.3	164.7	38	6.0
−12	20.4	163.8	40	8.1
−10	19.6	163.0	42	10.1
− 8	18.7	162.1	44	12.1
− 6	17.9	161.3	46	14.1
− 4	17.0	160.4	48	16.1
− 2	16.1	159.5	50	18.1
0	15.2	158.6	52	20.1
+2	14.3	157.7	54	22.1
4	13.4	156.8	56	24.1
6	12.5	155.9	58	26.1
8	11.6	155.0	60	28.1
10	10.7	154.1	62	30.1
12	9.7	153.1	64	32.1
14	8.8	152.2	66	34.1
16	7.8	151.2	68	36.1
18	6.9	150.3	70	38.1
20	5.9	149.3	72	40.1
22	5.0	148.4	74	42.1
24	4.0	147.4	76	44.1
26	3.0	146.4	78	46.1
28	2.0	145.4	80	48.1
30	1.0	144.4	82	50.1
32	0.0	143.4	84	52.1
			86	54.1
			88	56.1
			90	58.0
			95	63.0
			100	68.0

AN ANEROID CALORIMETER.

By H. C. Dickinson and N. S. Osborne.

The term "aneroid calorimeter" is applied to a type of calorimeter in which equalization of temperature is secured by means of the thermal conductivity of copper instead of by the convection of a stirred liquid. The calorimeter described, which consists of a thick-walled cylindrical vessel of copper in the walls of which are embedded a coil of resistance wire to supply heat electrically, and a platinum resistance coil for use as a thermometer, has been found useful over a wide range of temperatures and is applicable to a variety of problems.

For use at low temperatures the calorimeter is mounted in a jacket surrounded by a bath of gasoline, the temperature of which can be controlled thermostatically to within a few thousandths of a degree at any temperature between $-55°$ and $+40°$ C. or can be changed rapidly in order to keep it the same as that of the calorimeter when heat is being supplied to the latter.

Differences in temperature between the surface of the calorimeter and that of the jacket are measured by means of multiple thermocouples which have ten junctions distributed over the surface of each, thus making it possible to apply accurate corrections for thermal leakage between calorimeter and jacket even when the temperatures of both are changing rapidly.

The platinum resistance coil (for use as a thermometer) embedded in the calorimeter shows slight irregularities in its behavior, probably due to the difference in expansion between the platinum and the copper which surrounds it. Uncertainties on this account, while in general negligible, can be avoided by measuring the temperature of the outer bath with a standard resistance thermometer, using the thermocouples to measure the small difference, usually not more than a few thousandths of a degree, between the calorimeter and the jacket. The thermometer could probably be improved by changing the construction.

Results of a series of experiments give the constants of the resistance thermometer and the heat capacity of the calorimeter, including a tin-lined cell for use in determining the specific heat of ice and water and the latent heat of fusion of ice.

A series of check experiments on the specific heat of water shows the order of reproducibility of results which can be obtained with this calorimeter to be 1 part in 2000. Measurements made at temperatures between 0° and 40° C. gave results which agree to within the limits of experimental accuracy with the unpublished results of a long series of experiments made in the usual form of stirred water calorimeter. The results are also in satisfactory agreement with the most probable values deducible from the data of the most careful investigations published by other observers.

A STUDY OF THE ATTERBERG PLASTICITY METHOD.*

ATTERBERG evaluates the plasticity of a clay in accordance with the range of water content within which it can be considered plastic. The plasticity value is expressed by a number obtained by subtracting the water content of the clay at the lower plasticity limit from the water content limit. The work of this investigator on Swedish clays is described and the results critically reviewed. The method was tried on twenty American clays and the results compared with evaluations based on per cent. water of plasticity, per cent. shrinkage, and per cent. water absorbed by the clay powders while in an atmosphere of high humidity. It was brought out that the Atterberg method does not give results which check observations made from actual experience with the clays, principally because it does not account for a sufficient number of factors. A revised adaptation of the Atterberg method is suggested in which the plasticity number is coördinated with the amount of water required to develop the best working properties of the clays. This scheme grouped the clays satisfactorily into those varieties which are sticky and would give trouble in working in a stiff-clay machine, and those which are non-sticky and admit of ready working.

CHARACTERISTICS OF RADIATION PYROMETERS.†

By George K. Burgess and Paul D. Foote.

[ABSTRACT]

IN the complete paper there have been given an account of the principles which form the basis for the operation of total radiation pyrometers, descriptions in some detail of representative types of this instrument, together with the results of an experimental study of their calibration and behavior under various conditions of use and as modified by changing the several factors which may influence the readings of such pyrometers. A considerable portion of the text is devoted to the examination of the sources of error and their elimination or correction.

---

* Technologic Papers of the Bureau of Standards, No. 46.

† To appear as a Scientific Paper of Bureau of Standards.

In all there were carefully examined some twenty instruments, including all the ordinary types commonly met with in practice, such as the four due to Féry, and the Foster, Thwing, and Brown pyrometers.

Although this investigation, which is largely made up of instrumental details, does not readily lend itself to a brief summary, yet the following conclusions of a general nature may be mentioned.

The Stefan-Boltzmann law $E = a\ (T^4 - T^4{}_o)$ is not in general, except by accident, obeyed in its exactness by any of the pyrometers examined. The similar equation $E = a\ T^4 . T^{b-4}$, in which b is slightly different from 4 (usually neglecting the T_o term), is, however, obeyed with sufficient exactness by all total radiation pyrometers.

The main factors influencing the value of the exponent b are the geometry and mechanical construction of the instrument; the value of b for 20 thermoelectric pyrometers ranged from about 3.5 to 4.5. The same instrument of the Féry type may have a different exponent, according to its use with or without the sectored diaphragm for increasing the temperature range.

In general, a radiation pyrometer behaves not as a " black " or total receiver of energy, but as a " gray " receiver for the ordinary range of temperatures. For the Féry pyrometer with a gold mirror, for example, the effect of selective reflection of the gold mirror does not become practically appreciable until above 2500° C., but may cause an error of 500° C. at the temperature of the sun.

The auxiliary apparatus, galvanometer or potentiometer, and recording devices, can be constructed so that their errors will be practically negligible. For the work of the highest accuracy the potentiometric method of measurement is to be preferred with thermoelectric radiation pyrometers.

The principal errors to which the several types of radiation pyrometers are subject are shown to lie in the design and mechanical construction of these instruments, and certain of these inherent errors, such as lag or slowness in reaching an equilibrium reading, require, for satisfactory results, that the pyrometer be calibrated and used under similar conditions of time of exposure, distance from and aperture of source. Wide variations in the lag effect exist among apparently similar instruments, ranging from a few seconds to an hour or more. These and other errors of appreciable magnitude, such as stray reflection, convection currents, intervening atmosphere, size of source, tarnishing of receiving mirror, etc., are discussed at length in the text.

It is shown that errors greater than 100° C. may readily be caused by dirt on or oxidation of mirror.

The magnitude of errors due to varying the focusing distance may amount to several hundred degrees if suitable precautions are not taken.

A convenient method for the rapid comparison of different types of pyrometer, and for determining the effects of size of aperture and focusing distance, was devised, consisting of a wide nickel (oxide) strip heated electrically, a series of circular, water-cooled diaphragms, and an optical bench.

The methods in use at this Bureau for the calibration of radiation pyrometers by means of especially designed experimental "black bodies" are described in detail and methods of extrapolation outlined, as well as methods of use of radiation pyrometers, including methods of obtaining approximately correct temperatures for the case in which a source of insufficient size is sighted upon.

Finally, there is considered the application of the radiation pyrometer to the determination of the total emissivity of nonblack substances and to the measurement of temperatures.

Reciprocal Action of Cerium and Hydrogen. I. I. JOUKOFF. (*J. Russ. Phys.-Chem. Soc.*, xlv, 2073; *Bull. Soc. Chem.*, xvi, 531.)—Cerium, when heated in an atmosphere of hydrogen, rapidy absorbed the gas at about 350° C. Between 450° and 510° C. the dissociation pressure was about 1 mm. so long as the proportion of hydrogen did not exceed that corresponding to CeH_2; beyond this the dissociation pressure increased with the hydrogen concentration. It is concluded that the hydride CeH_2 is formed, and that this hydride is capable of dissolving hydrogen.

Electric Transmission of Vision. G. RIGNOUX. (*Comptes Rendus,* clix, 301.)—In the transmitting apparatus a number of selenium cells are employed—as many, in fact, as the number of points to be transmitted. The currents furnished by the selenium cells being too small to be used with an apparatus for the magnetic rotation of the plane of polarization of a beam of light, each selenium cell is connected to a relay. Similar terminals of these relays are connected to the sectors of a commutator, so that each is connected in turn through a battery to the coil of the polarization apparatus. Along the axis of the coil there is a tube of carbon tetrachloride, through which a beam of polarized light is sent. A nicol at the end of the tube transmits more or less light, according to the amount of rotation of the plane of polarization of the light in its passage through the tube. An arrangement of lenses and rotating mirrors serves to direct the emergent beam to a point on a screen corresponding to the particular selenium cell which is at any particular instant in use. Thus a series of points, corresponding in brightness or darkness to points on the object to be viewed at a distance, is obtained on the screen, and if these succeed one another with sufficient rapidity the persistence of vision allows the whole of the object to be seen at once. A rough apparatus on these lines has been made, and letters or other objects presented to the transmitter have been seen projected on the screen of the receiving apparatus. Various points in which the apparatus may be improved are noted. The disadvantage of the relays is that they will give no gradation; they either operate or do not operate. It is thought that by utilizing a small type of dynamo a continuous gradation of current may be obtained, corresponding to the luminous intensity received by each cell.

New Method for Fumigating Imported Seed.—A satisfactory method for destroying injurious insects in imported seed without affecting the value of the seed has been used by the United States Department of Agriculture, and is described in a new bulletin (No. 186), entitled "A Method of Fumigating Seed."

In the new method the infested seed is placed in a chamber in which a partial vacuum has been created. The chamber is then filled with a very deadly gas—hydrocyanic acid—which penetrates more effectively into the seed because of the previously-created vacuum. It has been found that a considerably shorter exposure was necessary in using this method of fumigation than in the usual method. The bulletin describes the experiment completely, giving details and illustrations of the chamber used in the experiment.

Hydrocyanic acid is, of course, a most dangerous poison and should not be handled by any except those who are thoroughly familiar with it. Another gas—carbon bisulphide—is to be used by the department in a similar experiment, the results of which will be announced later.

THE FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting held Wednesday, March 17, 1915.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 17, 1915.

PRESIDENT WALTON CLARK *in the Chair.*

Additions to membership since last report, 6.

The paper of the evening, on "High Temperature Investigations," was read by Dr. Edwin F. Northrup, of the Palmer Physical Laboratory, Princeton University. A summary was presented of the results of investigations by the speaker in the measurement of high temperatures. New furnaces for the production of high temperature were shown in operation for the first time.

A high temperature pyrometer and resistometer, recently devised, was also exhibited and described. The problems of electrical conductivity at high temperatures and the electrical conduction of metals in liquid and vapor states were given consideration.

The subject was illustrated by lantern slides and numerous experiments. After a discussion by Drs. Richards and Goldsmith, Messrs. Snook, Fulweiler, Spencer, and others, the thanks of the meeting were extended to Dr. Northrup.

Adjourned.

R. B. OWENS,
Secretary.

(Proceedings of the Joint Meeting held Friday, March 19, 1915.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 19, 1915.

A joint meeting of the Institute and the Philadelphia Section of the Illuminating Engineering Society was held in the Hall of the Institute on Friday evening, March 19, 1915, at 8 o'clock.

Dr. George A. Hoadley and Mr. H. A. Hornor presided jointly.

A paper on "Method of Securing Uniformity of Readings on the Flicker Photometer with Different Observers," by Herbert E. Ives and E. F. Kingsbury, was presented by Dr. Ives.

Professor John Hammond Smith, of the University of Pittsburgh, read a communication on "Photo-Sculpturing." The papers were illustrated by lantern slides and experiments.

A discussion ensued in which Dr. Hoadley, Messrs. Hornor, Bond, Rowland, and others took part.

Adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, March 3, 1915.*

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 3, 1915.

MR. GEORGE R. HENDERSON *in the Chair.*

The following report was presented for final action:

No. 2586.—Dobbins's Daylight Rods. Edward Longstreth Medal of Merit to Edward J. Dobbins, of London, England, adopted.

R. B. OWENS,
Secretary.

AWARD OF THE EDWARD LONGSTRETH MEDAL OF MERIT.

Mr. Edward J. Dobbins, of London, England, has been awarded the Edward Longstreth Medal of Merit for his Daylight Rods. These rods have been designed for use in increasing the daylight illumination of interior spaces, for which purpose they replace prismatic glass glazed into windows, canopies, or mirrors. Each rod is of clear glass and is cylindrical, with a longitudinal groove one side of which is flat and the other formed of lenses of small curvature. A number of the rods are mounted in a frame fastened outside and flush with the window frame. When mounted, the rods have their axes parallel, and by a special arrangement all can be revolved together and set to any desired angle. The same form of rod can be used in all conditions of lighting, and the rods can be easily cleaned and replaced if broken.

SECTIONS.

Section of Photography and Microscopy.—A joint meeting of the Section and of the Photographic Society of Philadelphia was held in the Hall of the Institute on Thursday, February 25, 1915, at 8 P.M.

Dr. Henry Leffmann presided.

Mr. Henry Hess, M.E., of Philadelphia, Pa., delivered a lecture, entitled "Recent Progress in Making Photographs in Color." By means of lantern slides the speaker explained the laws and phenomena underlying color photographic processes. He gave several examples of the results obtained by means of those particular processes which require very little skill.

After a brief discussion the thanks of the meeting were extended the speaker.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held in the Hall of the Institute on Thursday, March 4, 1915, at 8 P.M.

Mr. George R. Henderson, president of the Section, occupied the chair.

Mr. Carleton E. Davis, Chief, Bureau of Water, City Hall, Philadelphia, Pa., delivered a lecture, entitled "Hydraulic Works of the Panama Canal." The speaker dealt more particularly with the provisions of water works and sewers in the Canal Zone and in the cities of Panama and Colon. In this connection he described the draining and ditching of certain areas and the construction of modern hydraulic works in others to render the entire zone free from insects and the workers on the canal immune from malaria and yellow fever. He stated that this preliminary work was of such significance as to justify giving it a permanent place in the records of the building of the canal.

A vote of thanks was extended the speaker and the meeting adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, March 10, 1915.*)

RESIDENT.

MR. RONALD G. COOLBAUGH, 32 North Front Street, Camden, N. J.

NON-RESIDENT.

MR. JOHN H. BARR, 293 Broadway, New York, N. Y.
MR. ELBRIDGE L. GIBBS, 1928 Oak Street, Jacksonville, Fla.
MR. NATHAN E. LEWIS, 85 Liberty Street, New York, N. Y.
MR. EUGENE L. MAINES, 195 Exchange Street, Rochester, N. Y.
MR. ORVILLE CAMPBELL SKINNER, "Open Hearth," Burnham, Pa.

CHANGES OF ADDRESS.

MR. CHARLES E. BENNETT, 461 Gas and Electric Building, Atlanta, Ga.
MR. WILLIAM B. HALSEY, Locust Avenue and Stewart Street, St. Albans, Long Island, N. Y.
MR. JOHN W. HORNSEY, Summit, N. J.
MR. JOHN S. ROOKE, 2002 North 29th Street, Philadelphia, Pa.

NECROLOGY.

William O. Griggs was born in 1845 and died on February 21, 1915. He was a graduate of the Jefferson and Hahnemann Medical Colleges.

Dr. Griggs became a life member of the Institute in November, 1889, and in 1903 was elected to membership in its Committee on Science and the Arts. He served as chairman of this committee during 1907, and for a number of years was very active, taking part in many investigations.

He was greatly interested in firearms, and his extensive collection was recently deposited in the armory of the Second Regiment, National Guard of Pennsylvania, where it will become a permanent memorial.

LIBRARY NOTES.

PURCHASES.

ABEGG, R., and AUERBACH, F., ed.—Handbuch der anorganischen Chemie. 6 volumes.: vol. 2, parts 1 and 2; vol. 3, parts 1 to 3; vol. 4, part 2. 1908–1913.

COOPER, MADISON.—Practical Cold Storage. 1914.

COSGROVE, J. J.—Sanitary Refrigeration and Ice Making. 1914.

Engineering Index.—31st Annual. 1914.

FORTIER, SAMUEL.—Use of Water in Irrigation. 1915.

GALILEI, GALILEO.—Dialogues Concerning Two New Sciences. 1914.

HALSEY, F. A.—Methods of Machine Shop Work. 1914.

LUHR, OTTO.—Mechanical and Refrigerating Engineer's Handy Book. 1913.

LYMAN, THEODORE.—Spectroscopy of the Extreme Ultra-violet. 1914.

MATTHEWS, J. M.—The Textile Fibres. 1913.

Photograms of the Year. 1914.

RICHMOND, HENRY DROOP.—Dairy Chemistry. 1914.

ROSENHAIN, WALTER.—Introduction to the Study of Physical Metallurgy. 1914.

SMITH, C. W.—Construction of Masonry Dams. 1915.

SODDY, F.—Chemistry of the Radio Elements. 1915.

TREADWELL, F. P., and HALL, W. T.—Analytical Chemistry, vol. 1, Qualitative; vol. 2, Quantitative. 1914.

GIFTS.

American Metal Company, Ltd., Comparative Statistics of Lead, Copper, Spelter, Tin, Aluminium, Quicksilver, and Silver. Frankfort-on-the-Main, 1914. (From the Company.)

American Society of Mechanical Engineers, Year Book, 1915. New York, no date. (From the Society.)

Barringer, D. M., Meteor Crater in Northern Central Arizona. No place, no date. (From the Author.)

British Board of Trade, Seventeenth Abstract of Labour Statistics. London, 1915. (From the Board of Trade.)

Buck & Hickman, Ltd., Catalogue of Lathes. London, no date. (From the Company.)

Canada Department of Mines, The Physical Properties of The Metal Cobalt, Part 2; Economic Minerals and Mining Industries of Canada. Ottawa, 1914. (From the Department.)

Carnegie Institution of Washington, Year Book, 1914. Washington, 1915. (From the Institution.)

Chain Belt Company, Catalogue No. 56 of Malleable Iron and Steel Chain Belts. Milwaukee, no date. (From the Company.)

Clark University, Register and Twenty-seventh Official Announcement. Worcester, 1915. (From the University.)

Colorado Bureau of Mines, Thirteenth Biennial Report. Denver, 1914. (From the Bureau.)

Crouse-Hinds Company, Condulet Catalogue No. 1000. Syracuse, 1914. (From the Company.)

Dixon, Joseph, Crucible Company, Graphite. Jersey City, 1914. (From the Company.)

Finlande l'Administration generale de l'industrie, Meddelanden 61st part, Suomen Teollisuushallituksen Tiedonantoja. Helsingissa, 1914. (From the Patent Office of Finland.)

Glidden Varnish Company, Catalogue of Machinery Finishes. Cleveland, no date. (From the Company.)

Institution of Civil Engineers, Proceedings. Westminster, 1914. (From the Institution.)

Institution of Mining and Metallurgy, Transactions. London, 1914. (From the Institution.)

Jenkins Brothers, Catalogue No. 20 of Valves, Packing and other Mechanical Rubber Goods. No place, no date. (From the Company.)

Kungl. Vitterhets Historie och Antikvitets Akademien, Antikvarisk Tidskrift. for Sverige. Stockholm, no date. (From the Academy.)

Leland Stanford Junior University, An Introduction to the Study of the Endocrine Glands and Internal Secretions. Stanford University, 1914. (From the Library of the University.)

Massachusetts Institute of Technology, Reports of President and Treasurer. Boston, 1915. (From the Institute.)

Massachusetts State Board of Health, Forty-fifth Annual Report, 1913. Boston, 1914. (From the Board of Health.)

Museu Nacional do Rio de Janeiro, Archivos, vol. xvi. Rio de Janeiro, 1911. (From the Museum.)

New Orleans Board of Health, Biennial Report, 1912–1913. New Orleans, no date. (From the Board of Health.)

New York Public Library, January Bulletin. New York, 1915. (From the Library.)

North Western Expanded Metal Company, Designing Data for Reinforced Concrete. Chicago, 1914. (From the Company.)

Nova Scotia Department of Public Works and Mines, Annual Report, 1914. Halifax, 1915. (From the Department.)

Pelton Water Wheel Company, Catalogue of Turbine and Tangential Water Wheels. San Francisco, 1914. (From the Company.)

Pennsylvania Commission of Soldiers' Orphan Schools, Annual Report. Harrisburg, 1914. (From the State Librarian.)

Pennsylvania Commissioner of Health, Sixth Annual Report, 1911, parts 1 and 2. Harrisburg, 1913. (From the State Librarian.)

Pennsylvania Department of Labor and Industry, Commissioner's Report, part 1, 1913. Harrisburg, 1915. (From the State Librarian.)

Pennsylvania Railroad Company, The Record of Transportation Lines, 1914. Philadelphia, 1915. (From the Company.)

Pennsylvania State Highway Department, Report, 1913–1914. Harrisburg, 1915. (From the State Librarian.)

Pennsylvania Superintendent of Public Instruction, Report. Harrisburg, 1914. (From the State Librarian.)

Pennsylvania Topographic and Geologic Survey, Report No. 9. Harrisburg, 1913. (From the Survey.)

Pennsylvania Water Supply Commission, Annual Report, 1913. Harrisburg, 1914. (From the State Librarian.)

Polytechnic Institute of Brooklyn, Catalogue of The College of Engineering, 1915–1916. Brooklyn, no date. (From the Institute.)

Princeton University, Catalogue. Princeton, 1914. (From the University.)

South Dakota Railroad Commission, Report, 1914. Pierre, no date. (From the Commission.)

St. Louis University, Bulletin. St. Louis, 1915. (From the University.)

St. Louis Malleable Casting Company, Catalogue No. 400 of Overhead Pole and Line Hardware. St. Louis, 1915. (From the Company.)

Tennessee Railroad Commission, Report. Jackson, 1914. (From the Commission.)

United States Brewers' Association, Year Book. New York, 1914. (From the Association.)

United States Cast Iron Pipe and Foundry Company, General Catalogue of Cast Iron Pipe. Burlington, 1914. (From the Company.)

University of Pennsylvania, Catalogue, 1914–1915. Philadelphia, 1915. (From the University.)

University of Rochester, Annual Catalogue, 1914–1915. Rochester, no date. (From the University.)

University of Western Australia, Calendar, 1915. Perth, 1914. (From the University.)

Vanderbilt University, Bulletin. Nashville, 1915. (From the University.)

Western Electric Company, Electrical Supply Year Book. New York, 1915. (From the Company.)

Winslow Safety High Pressure Boiler Company, Catalogue of Boilers. Chicago, no date. (From the Company.)

BOOK NOTICES.

LEAVENING AGENTS: Yeast, Leaven, Salt-rising, Fermentation, Baking Powder, Aërated Bread, Milk Powder. By Richard N. Hart, B.S. Easton, Pa., The Chemical Publishing Company, 1914. 78 pages and index, illustrations, 8vo. Price, $1.

This book contains a large amount of information, and will be especially useful to commercial analysts on account of material drawn from trade journals and other sources not ordinarily available in the laboratory. The principal topics are Yeast, Baking Powder, Aërated Bread, and Milk Powder, the latter being somewhat out of the scope of the book, but of value. Interesting information—obtained, the author states, from a private communication—is given as to the manufacture of compressed yeast. A good deal of historical detail is furnished under each of the topics.

The work is numerously illustrated, but many of the cuts are quite inferior. With the modern facilities for obtaining illustrations much better work could have been done with little extra expense. For the sake of some of the illustrations a heavy and moderately surfaced paper has been used which interferes with good press-work for the general text.

Of the literary style and mechanical execution less praise can be given than for the matter of the book. Typographic errors are not infrequent, sentence-forms are often involved, and common errors in grammar can be found. On page 48 "sauerteig" and "sauertig" occur in adjacent lines, in neither of which, by the way, is the word translated. On page 49 occurs the expression, "Is the salt-rising bacteria a single variety?" a sentence that contains almost as many errors as words. It means, of course, "Are the bacteria of salt-rising dough of one species?" The elaborate reaction-equations on page 52 are in some confusion, are of no use to the trained chemist, and unintelligible to the ordinary practical worker. On page 64 the analyst is directed to take one "grain" of baking powder for a certain test. Probably one gramme is meant. The table of composition and leavening power of baking powders (page 59) is incomplete and seems to contain several errors; for instance, the statement that Royal Baking Powder, analyzed in 1889, yielded only 15.3 cubic inches of gas per ounce of powder. Moreover, the table should state whether this is avoirdupois or troy ounce.

The practical value of this work to the food-chemist will ensure a wide sale; when the second edition is demanded, the author and printer should give more attention to literary form and typographic accuracy.

HENRY LEFFMANN.

EXAMINATION OF WATER FOR SANITARY AND TECHNIC PURPOSES. By Henry Leffmann, A.M., M.D., Ph.D. Seventh Edition, Revised and Enlarged, with Illustrations. 140 pages. Philadelphia, P. Blakiston's Son & Company, 1915. 12mo. Price, $1.25.

The present edition has been extensively revised and the procedures have been brought into general agreement with those recommended by the American Public Health Association. Additional new matter includes summaries of some of the later researches on corrosion of metals by water and details of methods of determining color turbidity and hardness. R.

PUBLICATIONS RECEIVED.

The Chemistry of Cyanogen Compounds and their Manufacture and Estimation, by Herbert E. Williams. 423 pages, 8vo. Philadelphia, P. Blakiston's Son & Company, 1915. Price, $3.50.

Theory of Measurements: A Manual for Physics Students, by James S. Stevens, Professor of Physics in the University of Maine. 81 pages, 12mo. New York, D. Van Nostrand Company, 1915. Price, $1.25.

U. S. Geological Survey: Mineral Resources of the United States, calendar year 1913. Part i, Metals; part ii, Non-metals. 2 volumes, 8vo. Washington, Government Printing Office, 1914.

Canada Mines Department, Mines Branch: Economic Minerals, and Mining Industries of Canada. 78 pages, illustrations, map, 8vo. Researches on Cobalt and Cobalt Alloys, conducted at Queens University, Kingston, Ontario. Part ii, The Physical Properties of the Metal Cobalt, by H. T. Kalmus and C. Harper. 48 pages, illustrations, plates, diagrams, 8vo. Ottawa, Government Printing Bureau, 1914.

North Carolina Geological and Economic Survey: Economic Paper No. 39, Proceedings of the Good Roads Institute held at the University of North Carolina, March 17–19, 1914, under the auspices of the Departments of Civil and Highway Engineering of the University of North Carolina and the North Carolina Geological and Economic Survey. 117 pages, illustrations, 8vo. Raleigh, State Printers, 1914.

U. S. Bureau of Mines: Bulletin 84, Metallurgical Smoke, by Charles H. Fulton. 94 pages, illustrations, plates, 8vo. Miners' Circular 21, What a Miner can do to Prevent Explosions of Gas and of Coal Dust, by George S. Rice. 24 pages, 8vo. Technical Paper 80, Hand Firing Soft Coal under Power-plant Boilers, by Henry Kreisinger. 83 pages, illustrations, 8vo. Washington, Government Printing Office, 1915.

U. S. Bureau of Standards: Scientific Papers No. 243, The Emissivity of Metals and Oxides. III, The Total Emissivity of Platinum and the Relation between Total Emissivity and Resistivity, by Paul D. Foote, Assistant Physicist. (Reprinted from Bulletin of Bureau of Standards, vol. ii.) 6 pages, 8vo. Washington, Government Printing Office, 1915.

Oxford India Paper. ANON. (*Papierfabrikant,* xxii, 605.)—This paper, formerly made only in England, is now made in other countries; it must be as thin as possible, weighing under 30 grammes per square metre, non-transparent, and very resistant to ink penetration. It is made principally from linen rags, a "standard receipt" being 80 per cent. of best bleached white linen, 10 per cent. of best white bleached cotton, 5 per cent. of bleached straw pulp, 2 per cent. of finest white loading (*e.g.,* talc), 3 per cent. of waste. The rags are boiled with 1 to 2 per cent. of soda for 3 hours at 3 atmospheres pressure, washed carefully and bleached with 1 to 2 per cent. of chlorine until snow white. Ultramarine is used for coloring and indanthrene blue, R.S., for tinting. Beating is carried on for 20 to 34 hours in engines of up to 100 kilos. capacity, with sharp blades so as to obtain a short, non-transparent whole stuff. Cone engines have proved very suitable; sand traps must be used on pulping and beating machines. Paper machines of 150 to 170 centimetres width are most satisfactory, running at not more than 40 metres per minute; wire about No. 90. The strainers should be first a rotary strainer, followed by a flat one, having slots 0.4 mm. wide and fitted with an automatic cleaning device. Shaking should be severe and short. Suction should be weak and couchers and presses lightly loaded so that the paper may have a thick handle. Stone rollers should be employed for the wet-press. The paper must be lightly calendered; moist calendering is not used.

CURRENT TOPICS

Ozonization of Air. M. W. FRANKLIN. (*J. Ind. Eng. Chem.*, vi, 850.)—*Ventilation.*—The modern practice of ventilation is concerned only with the absorption of heat produced by the inmates of a room, with removal of the expired moisture, and destruction of the odors of men, animals, and organic substances. Ozone is most useful in those places where perfect ventilation is impossible. It does not simply mask the organic odors, but destroys them. Onions, decayed fish, decomposed meat, etc., treated with ozonized air had a strong smell of ozone, and after treatment with ferrous sulphate solution to remove the ozone, the substances were free from their natural odor. Chemical compounds produced in the decomposition of organic matter, as skatol, and valeric and butyric acids, are destroyed also. No instance of harm to individuals from the use of ozone in proper concentration in air has been recorded; the workers in the London tube railways and those on water-sterilization plants have shown no ill effects. The use of ozone in quantity to sterilize the air of rooms involves irritation to the respiratory tract. Experiments to determine its germicidal action have given inconclusive results. Its usefulness is not due to any beneficial effects on the human economy, but to the fact that it destroys harmful organic emanations in the air.

Odor Destruction.—Disagreeable odors are given off in the manufacture of casein. Experiments with undried commercial casein showed that the odor was destroyed in the presence of ozonized air, and that the least quantity of ozone required was 1.84 milligrammes per litre of air contaminated with the odor from 15 grammes of casein. In experiments with tobacco smoke, it was found that ozone combined only with the volatile components of the smoke, rendering the smoke odorless, tasteless, and non-irritative, but that it did not oxidize the carbon particles. There was, however, a slight diminution in the smoke density when the air was ozonized: equal weights of tobacco were burned and the smoke collected with equal volumes of air and ozonized air, and in the bottle containing the latter mixture a marked clearing was effected in four hours as compared with the other bottle. Pieces of different kinds of cloth were exposed to tobacco smoke until they had a strong odor; they were then treated with ozonized air and were thoroughly deodorized within half an hour.

Food Preservation.—The effect of ozone on egg-albumin was examined, and it was found that considerable coagulation took place and the albumin turned a yellowish-gray color. Eggs were placed in bottles which were exhausted and then filled with ozonized air.

After ten days, all the ozone had disappeared and the bottles were recharged and examined every ten days. After sixty days the eggs ceased to taste fresh; the loss in weight was about 1.5 per cent. In a control series in the absence of ozone the eggs began to turn stale after twenty days, when the loss in weight was 0.5 per cent. The action of the ozone is to lessen the number and activity of the bacteria which penetrate the shell during evaporation under ordinary conditions.

Use of Electric Furnaces in Brass Foundries. H. G. DORSEY. (*Metallurgical and Chem. Engin.*, xii, 644.)—The furnace employed in these tests was of the Helberger type and of 100 kg. capacity. After describing the construction of the furnace and the tests made with it at the Cash Register Works at Dayton, Ohio, the author states that, considered commercially, this furnace is a failure. It shows many disadvantages and very few advantages. As a laboratory furnace, including experimental work in the foundry on new combinations, it possibly is a good type of furnace, provided a suitable crucible can be obtained. Almost any temperature may be reached and easily maintained for any considerable length of time, and if only a few heats were to be made per week the occasional renewing of crucible resistor, plates, etc., would not be troublesome. To prevent contamination of the metals, some other crucible material, however, would be necessary. For 55 heats five different crucibles were used—an average of only 11 heats per crucible. Working on the above basis no more than 11 or 12 heats could be melted per day, unless the furnace were operated at night, which would mean a new crucible every day. Unless an air blast were used to cool it, the furnace would scarcely get cool enough during the night to insert the crucible the next morning. Assuming ideal conditions, it would require about 31 kilowatt-hours per hundredweight to melt the metal, while the above tests show about 62 kilowatt-hours per hundredweight. Another disadvantage of the furnace is the fact that the crucible is long and narrow, and it is difficult to charge the metal in any quantity, unless the furnace-tender stay beside it and put the metal in piece by piece. This would mean that it would require one tender for each furnace, which would be rather expensive. In a more convenient form the crucible would be a short cylinder of large diameter, but electrically this would be bad, as it would necessitate greater currents. These tests seemed to eliminate the Helberger furnace as a competitor with pit-fires. Other types of furnaces are being tried, but no conclusions have yet been reached. In the discussion Gillett said that this paper gave the first account of commercial work with the electric furnace in a brass foundry. Because the Helberger furnace did not succeed under the conditions of the work at Dayton, it does not follow that all electric furnaces are inefficient. He also pointed out that in considering electric-furnace operations the energy needed to heat the furnace before the work is begun must be taken into consideration.

Relation between Brinell Ball Tests and Scleroscope Readings. J. J. THOMAS. (*Amer. Soc. Testing Materials,* 1914.)—Brinell and scleroscope readings were both taken on each of a large number of metals and alloys, and the results plotted with a view to obtaining a conversion factor. The Brinell tests were made with an "Alpha" machine, having a steel ball 10 mm. in diameter, with a pressure of 3000 kilos. for 30 seconds, and the scleroscope readings were taken with a Shore instrument having a diamond-tipped hammer. The factor for converting the scleroscope readings into the Brinell hardness number is 6.67 for steel, 5.25 for cast iron and bronzes, about 6 for aluminum, and 7.7 for nickel steels. Metals with a Brinell hardness number above 300, or scleroscope number above 45, were found difficult to machine. Tempered steels gave Brinell numbers from 150 to 300. The scleroscope readings varied more than the ball tests on a given sample, due probably to the very small area actually tested by the scleroscope.

Progress in Chemical Pulp Industry. A. KLEIN. (*Papierfabrikant,* xxii, 601.)—The majority of the materials used for paper making in Germany are derived from wood and straw, only about 5 per cent. of rags being employed. In Europe fir, pine, spruce, and large woods are principally used, together with some poplar and beech. Formerly the losses amounted to 20 per cent. from peeling and boring out branches, with 15 per cent. due to sawing into discs, 3 cm. thick; these losses are now reduced to 5 to 6 per cent. by hand peeling and 10 to 12 per cent. by mechanical peeling. Formerly only 22 to 35 per cent. yields of pulp were obtained; the sulphite process now yields 45 to 48 per cent., the sulphate process 35 to 38 per cent., and the soda process 30 to 38 per cent. By increasing the pressure in the digesters the time required in the sulphite process has been reduced from about 36 to 48 hours to 9 to 10 hours, while the use of mechanical stamps to ram the material in the digesters has increased the capacity to 85 to 95 kilos. per cubic metre. Vertical digesters have replaced the earlier horizontal type with improvement in speed of filling. Sulphite liquors containing large amounts of free acid are employed, and the incidental sulphuric acid is reduced by thorough cooling of the gases and absorption surfaces. The injurious effect of selenium in the pyrites used is almost wholly avoided by preventing the formation of dust in roasting. Mechanical pyrites roasting furnaces are employed, and rotary instead of stationary sulphur furnaces. The tower system of liquor preparation is now used more frequently than the tank system. By the recovery of waste gases and by reducing losses of gas and fibre the consumption of sulphur has been decreased considerably; formerly 100 kilos. of unbleached pulp required 45 to 90 kilos. of pyrites or 18 to 20 kilos. of sulphur; at the present time 25 to 26 kilos. of pyrites or 10 to 11 kilos. of sulphur suffice.

The older soda process using 5 to 5½ per cent. caustic soda solutions has been largely displaced by the sulphate process. This process uses liquors such as the following: 1.5 per cent. Na_2CO_3, 6.2 per cent. NaOH, 2.2 per cent. Na_2S, 0.3 per cent. Na_2SO_3, pressures up to 8 atmospheres being employed. The introduction of improved machinery and processes has led to the recovery of up to 90 per cent. of the soda instead of 58 per cent. as in former times. Of the numerous proposals for the utilization of waste liquors for the manufacture of, *e.g.*, tanning materials, fertilizers, feeding stuffs, dyes, alcohol, etc., the author states that none has given practical results; the most promising are the processes devised for alcohol production. Strehlenert's process seems to be practicable; in this the sulphite liquor yields alcohol, plaster of Paris, sulphur dioxide, and a fuel with a calorific value of 7000 calories. By Rinmann's process 500 kilos. of "carbon," 100 kilos. of spirit and acetone, and 100 kilos. of motor spirit are said to be recovered per ton of cellulose.

Bleaching of pulp is carried out by means of hypochlorites or by electrolytic chlorine. Formerly 100 kilos. of pulp required 30 to 35 kilos. of bleaching powder; 10 per cent. or less now suffices, with a loss of only 4 to 9 per cent. of fibre. Attention is called to the possibility of utilizing such materials as broom rice, flax straw, bamboo, savannah grass, maize stalks, etc.

The Artificial Color Industry and its Position in England. F. M. PERKIN. (*J. Soc. Dyers and Col.*, 1914, xxx, 339.)—After a brief review of the history of the coal-tar color industry, the causes which led or contributed to the decline of the industry in England are summarized thus: The exploitation of the work of English chemists in Germany owing to the imperfect British patent laws and the lack of patent laws in Germany during the earlier stages of the industry; slackness on the part of the early British manufacturers, after a certain period of prosperity; industrial chemical research carried out in Germany but neglected in England; German business organization; restrictions on the use of alcohol. The steps being taken to establish the industry on a large scale in England suggest that the firms now manufacturing colors should enlarge their output and obtain leave to work certain German patents; that many of the raw and intermediate products, such as benzene naphthalene, anthracene, and their derivatives, should be manufactured at one or two of the great gas works, and that a few new companies should be started, preferably with capital furnished, at least in part, by color users. In an industry such as that of the artificial colors a number of highly-trained research chemists must be employed, as success will rest with the works capable of turning out the largest number of new colors and at the same time improving the methods of manufacture and the quality of the older ones and devising means of profitably utilizing by-products. In this connection it is pointed out that the great profits made in the earlier stages of the industry by German firms were employed in the first case to write off capital expenditure, and, secondly, to reconstruct their works and provide well-equipped laboratories staffed with skilled research chemists. The restrictions on the use of alcohol have been considerably mitigated, largely owing to the efforts of T. Tyrer, but it is stated that there is room for considerable improvement in the administration of the government acts. The use of pure alcohol is of even greater importance in the manufacture of drugs and photographic chemicals—an industry almost entirely in German hands before the war—than in the color industry.

New Building of the Mellon Institute.—The new building which will form the permanent home of the Mellon Institute of Industrial Research and School of Specific Industries of the University of Pittsburgh was formally dedicated on February 26. The building is the gift of Messrs. Andrew William and Richard Beatty Mellon, of Pittsburgh, and was especially designed for the needs of the Institute. It is distinctly modern in every respect, and complete facilities are provided for the investigation of manufacturing problems and for conducting industrial research.

The new home of the Mellon Institute is a five-story-and-attic building. The basement contains seven rooms: the main storeroom, the boiler room, the electric furnace room, a heavy apparatus room, a room equipped for low-temperature work, the machine shop, and the kitchen. On the first floor are located the general offices, the library, the assembly hall, a special apparatus room, and a dark-room laboratory. The second and third floors each contains ten large research laboratories and nine small ones; the fourth floor, which is not finished, will contain an identical number of laboratories so soon as the growth of the Institute warrants its completion.

While the Mellon Institute possesses an endowment of its own and has its own Board of Trustees, it is an integral part of the University of Pittsburgh. The dedicatory ceremonies were accordingly held in conjunction with the annual Charter Day exercises of the University.

Tests of Automobiles at the Royal Technical University, Charlottenburg. A. RIEDLER. (*Engineering,* xcviii, 109.)—In these tests the car was placed on a test-bed with its wheels resting on rollers, the shafts of which were connected to two friction brakes and also to dynamos capable of being used as motors. The power can thus be measured either by the dynamos or by the brakes, so that the various items of both power and loss can be measured separately as nearly as possible under actual running conditions; *e.g.,* the motor is tested, mounted on the chassis. Tests are given of a 30-horse-power Rénault touring car, a 100-horse-power Benz racing car, a 70-horse-power Adler touring car, a Mercédès electromobile, a 35-horse-power Büssing military transport wagon, a 40-horse-power English Daimler-Knight car, and a Mercédès-Knight-engine; comparative tests were also made between the Knight and poppet-valve systems. In the tests the following points were apparent, viz.: a large increase of power is obtainable by the use of large valves; the loss of power between the engine and the back wheel rises with the engine speed; although the top speed is direct in all four cars tested, the loss by gearing does not seem to increase materially on the lower speeds; the loss through rolling resistance of the wheels (21 per cent.) is greater than that through friction in transmission (12.7 per cent.), the loss in the back wheels (16.2 per cent.) being far greater than that in the front (4.8 per cent.): the figures are given for a Rénault car running at 37½ miles per hour. On the lower speeds, when the driving stress is very high, the rolling resistance is found to be sometimes as much as ten times that of the same wheels running light. The efficiency of the transmission gear of the English Daimler with worm-drive is given as varying from a minimum of 84 per cent. on the lowest speed to a maximum of 90 per cent. on the top.

New Paths of Physical Knowledge. M. PLANKS. (*Phil. Mag.*, xxviii, 60.)—The fundamental changes in the main structure of physical theories are essentially constructive—not destructive—leading to modification and amplification of existing theory by the old way—conflict between experimental fact and portions of hitherto accepted theory. Now as before, the great physical principles still hold the field; *e.g.*, the conservation of energy, the conservation of momentum, least action, the chief laws of thermodynamics. But assumptions hitherto accepted almost without question are proving untenable, or at any rate doubtful; *e.g.*, the invariability of chemical atoms, the mutual independence of space and time, and the continuity of all dynamical effects. The fact of heat evolution by radium compounds placed the first in conflict with the conservation of energy, and the principle holds the field. If relativity be assumed to be experimentally established, the mutual independence of space and time comes into conflict with the so-called principle of the constancy of the velocity of light established by the electrodynamics of Maxwell and Lorentz. The latter has so far held the field, and it is not at all probable that any abandonment of that position will occur. The assumption of the continuity of all dynamical effects had long been accepted as a basis for all physical theories, but is now found in direct conflict with the experimental facts which have given rise to the quantum hypothesis. The disintegration of the energy of motion of water waves by continuous diminution of amplitude does not proceed indefinitely, but finds a certain limit in the size of the atoms. The atoms hold the energy together in a way, each atom representing a certain finite material quantum which can move only as a whole, and the larger the atoms the less can the total energy of motion be subdivided. This is quite in accordance with classical theory, but according to this the disintegration should proceed without limit in the case of the repeated reflection of light waves within a hollow enclosure—the infrared and visible rays should gradually disappear and become converted ultimately into invisible ultraviolet or chemical rays. But of such a phenomenon no trace is discoverable in Nature. The conversion here also attains, sooner or later, a perfectly definite and assignable limit, and after that the radiation conditions remain stable in every respect. The old theory proved untenable, but the principles of thermodynamics have shown themselves to be unshakable. The only solution of the riddle appears to be that, even in the case of the immaterial light and heat rays, certain processes must be at work which hold together the energy of radiation in definite finite quanta, and unite it the more strongly the shorter the waves, and the greater, therefore, the oscillation frequency. In what way we are to conceive the nature of merely dynamical quanta we cannot yet say for certain, but the hypothesis has certainly led to the idea that there are changes in Nature which occur, not continuously, but explosively. Moreover, the quantum hypothesis affords solutions of still more recent discoveries which are in conflict with the classical theory; *e.g.*, of the observed fact that to raise a piece of copper through one degree at 250° C. requires only about one-thirtieth of the heat required to raise it through one degree at 0° C., and that if we took the original temperature of the copper still lower, the corresponding quantity of heat would turn out many times smaller, without any assignable limit. The quantum hypothesis has also led to the most important result that the forces controlling the thermal oscillations in a solid are of the same kind as those which control its elastic oscillations, enabling us to calculate the thermal energy of a monatomic substance at various temperatures from its elastic properties, a performance far beyond the reach of the classical theory. Puzzling though the nature of dynamical quanta may be, it is difficult to doubt their existence, in some form or other; for whatever we can measure must exist.

Camphor Production in India. (*Chamber of Commerce J.*, December, 1914.)—The camphor tree (*Cinnamomum camphora*) has been successfully planted in Burma, Ceylon, and the Federated Malay States. In Burma there are plantations in the upper Chindwin, Myitkyina, Bhamo, and southern Shan States. There are experimental plantations in the Nilghiri Hills and in certain isolated patches of Bombay and Madras. In Ceylon the tree grows only in the more elevated parts: there is a plantation at Hakyala. Great difficulty has always been experienced in getting good seed imported direct from Japan, and there is often wholesale failure to germinate. The seeds sown for the Burma plantations were obtained from Hong Kong. Camphor is obtained also from an evergreen shrub (*Blumea balsamifera*) which is indigenous to the Shan States of Burma. It also grows in the islands of Hainan and Formosa and in South China.

Telegraphy with Alternating Currents. (British Patent 18,321 of 1913; *Elect. Engineering*, x, p. 487.)—The patent refers to a system of telegraphy in which alternating or interrupted current can be used for ordinary telegraphic signalling, and is stated to be particularly applicable to ocean cables. An alternator is used for transmitting purposes; one pole is earthed, the other being connected through a signalling key, condenser, and sensitive relay to the line circuit. The apparatus is the same at each end of the line, the sensitive relay controlling a sluggish relay, which in turn controls a sounder. Thus firm Morse signals appear on the sounder. It is stated that when alternating current is used for signalling the capacity and resistance of the cable do not interfere with the speed of working, as in the case of direct-current systems.

A New Reagent for Etching Mild Steel. W. ROSENHAIN and J. L. HAUGHTON. (*Iron and Steel Inst. Journ.,* lxxxix, 515.)—To obtain satisfactory results the following formula must be followed with considerable exactness: Ferric chloride 30 gm., concentrated hydrochloric acid 100 c.c., cupric chloride 1 gm., stannous chloride 0.5 gm., water 1 litre. In pure carbon steels the resulting pattern is the reverse of that produced by picric acid, but the most important property of the new reagent lies in the fact that it reveals in an unmistakable manner the distribution of phosphorus in mild steels, yielding results which are comparable with those obtained by heat-tinting. The cause of the pattern is the deposition of very thin films of copper. In unhardened steels ferrite is colored black, while in hardened steels martensite is developed in a remarkably clear manner. In commercial steels patterns identical with those obtained by heat-tinting are produced. The new reagent is extremely sensitive to the presence of phosphorus, the ferrite containing the least amount of phosphorus in solution being darkened first. It is therefore much more sensitive than picric acid in revealing the presence of ghosts. It appears that the width and distribution of the phosphorus banding depend upon the size and arrangement of the crystals in the original ingot. There is always considerable darkening round the enclosures of slag and sulphides in steel, which appears to indicate that there is a concentration of dissolved impurities in the immediate vicinity of such enclosures.

Stress Distribution in Engineering Materials. (*Engineering,* xcviii, 315.)—The object is to collect complete and systematic data on the stress distribution in a dead, mild steel containing 0.12 per cent. carbon, an axle steel containing 0.3 per cent. carbon, and a nickel steel. In a preliminary report Rogers gives an outline of the method of manufacture of the dead, mild steel, and Filon and Coker summarize the methods which have been proposed and used for the determination of the distribution of stress and strain in solids.

PRESS OF
J. B. LIPPINCOTT COMPANY
PHILADELPHIA

JOURNAL
OF
THE FRANKLIN INSTITUTE
DEVOTED TO SCIENCE AND THE MECHANIC ARTS

VOL. CLXXIX MAY, 1915 No. 5

CONDITIONS AFFECTING THE SUCCESS OF MAIN LINE ELECTRIFICATION.*

BY

W. S. MURRAY,
Consulting Engineer, New York, New Haven and Hartford Railroad Company.
Member of the Institute.

BEFORE touching upon the conditions affecting the success of main line electrification, perhaps it would be best to address ourselves to the question as to what constitutes success. A successful electrification may be considered as such from several viewpoints, and this leads to the necessity of a clear understanding with regard to projected results, both on the part of the railroad and the public.

A successful electrification means, of course, successful transportation by electric motive power. Classifying success into its broadest terms, an electrification may be:

1. A success for the public.
2. A success for the railroad.
3. A success for both the public and the railroad.

Naturally the greatest objective is the attainment of No. 3 of the above classification.

The railroad is vitally interested in the pronouncement by the people as to whether its electrification is successful or not, and, while the viewpoint of the railroad is identical with that of

---

* Presented at the joint meeting of the Institute and the Philadelphia Section, American Institute of Electrical Engineers, held January 20, 1915.

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

Copyright, 1915, by THE FRANKLIN INSTITUTE.

the people throughout their range of vision. looking at it, however, from the purely railroad side, a successful electrification, besides this, must answer the dictates of good business, which in turn are governed by the rules of economic consideration.

In latter times the tremendously decreased gross earnings and a complementary increase in operating expenses have so greatly reduced the net incomes of the railroads that the public have awakened to the fact that they are staggering under a financial load which, if not modified or alleviated in some way, will shortly make receivership the rule rather than the exception.

A few years ago a movement was started by the public to require the railroads to electrify, this being directed towards roads of large size with their attendant city yards and terminals. There were two principal and logical factors against the justice of this demand, the first being that at that time there was very little statistical information as to form, application, and economic result of electrification; and, second, due to the extremely grave financial situation as above described, it was patent that the railroads could not possibly carry the increased financial obligations that such a demand necessitated. The public were thus brought face to face with the undeniable conclusion that they were demanding something impossible, and so there has been a pause on their part, which has indeed been gratefully received by the railroads of this country. Let it be said that this very pause will later shed its dividends over many, for during this time the few railroads that had committed themselves to electrification have had an opportunity to study it in all of its important details and ramifications, and later, after an adjustment has been made whereby the solvency of the railroads of this country is guaranteed by a proper relation between transportation rates and operating expenses necessary to the safe conduct of their business, with enough left over to provide a reasonable return on a fair valuation of the property in use, then, and only then, will the railroad companies be able to do what to-day they cannot, namely, attract new capital required for electrification; and so, while a reference to this matter may be slightly off the subject of this paper, yet I cannot but take this opportunity to say in the abstract that this is indeed an important condition precedent to successful electrification.

The pause has given us a chance to learn many things about electrification. I do not believe that I would be conveying information to many who have studied the subject to say that there are probably one hundred places at this moment where conditions are such as to ensure successful electrification. For example, there is one situation I have in mind where an expenditure of $5,000,000 would yield beyond peradventure a return of 20 per cent.; this as measured against the present steam operation of the territory contemplated for electrification, and yet in the same breath it might be said that if the yield could be shown to be 40 per cent. instead of 20 per cent. the electrification of that territory would be denied, and rightly, too. Why? Because, for roads sufficiently large to consider electrification, a sum of this size is small in comparison to their existing capital investment, and a proper relation must first be established between capital already invested and the return upon it before further charges against capital account are made, no matter how attractive the return on the proposed betterment may be.

Quite a number of trunk line railroads, both in this country and abroad, have been studying electrification. The New York, New Haven and Hartford Railroad has not only been studying it most carefully, but has also had the opportunity of assembling data from the practical experience of operation with a range of application that includes all classes of transportation. Millions of ton miles in these several services have been actually recorded in the logs of the road's operation. In passenger service alone for the year 1913, 2,182,000 electric passenger locomotive miles were recorded, which alone would represent approximately 600,000,000 ton miles. The part of the New Haven system that has been electrified constitutes its most important division, extending from New Haven to New York, and on its main line, yards, sidings, and spurs every class of railroad movement is being daily made by electricity. A brief physical description of this division may be as follows:

Route mileage electrified, 73 miles, of which 61 is of four tracks and 12 of six tracks, thus giving a total main line mileage, measured in single track, of 316. To this may be added 184 miles of yards, sidings, and spurs, thus making a grand total, measured upon a single-track basis, of 500 miles. It is of interest to note that of the yards electrified one includes 35 miles, the other 25 miles.

Electric power is supplied to this extensive mileage from a single station, centrally located, but which, in a short time, will be supplemented by other supplies to be applied at the east and west ends of the electrification zone. There are 100 passenger, freight, and switching electric locomotives, and 69 multiple-unit cars. One main electrical shop has been completed, the capacity of which permits the maintenance and repairs of the above-mentioned electric motive power. Facilities for inspection of electrical equipment are also provided at various points in the electrification zone, the more important points being, of course, at termini.

To date, over $15,000,000 has been expended on this electrical transportation plant as above described. While such a figure represents the cash outlay, there have accrued to its appropriation accounts, during the process of construction, large credits for steam equipment replaced, as, for example, the 150 steam locomotives which have been transferred to other parts of the New Haven system, and the steel bodies of the multiple-unit equipment, which would have been purchased even had not the electrification been undertaken.

Descriptive of the electric movement on the New Haven electrification zone, the following facts with regard to passenger, freight, and switching service may be of interest:

Passenger.

At the present time all passenger service west of Stamford, Conn., is electrically operated. For the winter time-table now in effect, excluding Sundays, the schedule calls for 68 trains per day into Grand Central Terminal, two through trains terminating in Harlem River Station and the same number of trains out of the Grand Central Terminal and Harlem River, or a total of 140 trains per day.

The Harlem River Branch service includes 19 trains each way per day, except Sundays, between New Rochelle and Harlem River.

On the New Canaan Branch 16 trains are operated each way between Stamford and New Canaan.

This makes a total week-day schedule of 210 trains per day. Additional trains in and out of Grand Central Terminal are operated on Saturdays, and extra trains are also run on the Harlem River Branch on Sundays.

Of the 70 through trains per day between Grand Central

Terminal, or Harlem River, and New Haven, 46 are electrically operated the entire distance, steam locomotives being used between New Haven and Stamford on the remaining 24 trains.

Of the 210 trains per day, 114 are hauled by electric locomotives, multiple-unit equipment being used on the remaining 96 trains.

Forty-eight A.C.-D.C. locomotives are used in passenger service. The multiple-unit equipment at the present time comprises four A.C. motor cars, 21 A.C.-D.C. motor cars, and 46 trailers.

The average number of electric train miles per day is about 6600, of which 1400 are made by multiple-unit equipment, the remaining being trains hauled by electric locomotives.

The passenger locomotives make an average of 8200 miles per day, some of the individual locomotive mileages being as high as 450 to 500 miles. Forty-one of the 48 passenger locomotives used in A.C.-D.C. service were originally designed to haul trains of 200 tons trailing weight in local service, 250 tons in local express service, and 300 tons for through express service between New York and New Haven. At the present time two of these locomotives are used only on through express trains where the trailing weight exceeds 390 tons, and two locomotives may also be used on heavy local trains.

New flash boilers have recently been installed in these 41 locomotives, of increased capacity, to provide for steam heating of through passenger trains between New York and New Haven. This is accomplished successfully. Through service between New York and New Haven was inaugurated in June, 1914, and these locomotives easily make their running time in express service.

The remaining seven A.C.-D.C. passenger locomotives were originally designed to haul local trains of 350 tons trailing weight or express trains of 800 tons trailing weight at a maximum speed of 45 miles per hour. In actual service these locomotives attain a maximum speed of 55 miles per hour.

The multiple-unit motor cars make an average of 2100 miles per day. The proportion of trailers to motor cars for A.C.-D.C. equipment averages two trailer cars to one motor car. On the New Canaan Branch the proportion is one trailer car per motor car, while on the Harlem River Branch about one-half the trains have two trailers per motor car, the remaining trains consisting of a motor car and one trailer.

Of the 96 trains operated per day by multiple-unit equipment, 38 are Harlem River Branch locals, 32 are New Canaan Branch locals, and the remaining 26 are either locals or local express trains between New York, New Rochelle, Port Chester, Stamford, and New Haven.

Freight.

Thirty-six A.C. locomotives are used in freight service. These are geared locomotives of 1400 horse-power each and designed originally to haul a trailing load of 1500 tons in through service at 35 miles per hour, although they are used at times for heavy passenger service in the A.C. zone during the summer months, when heating of the trains is not required. Some of these A.C. locomotives are used in transfer service between Oak Point and Westchester freight yards on the Harlem River Branch, others in way freight and switching service, but the majority are used on through freight trains between Harlem River and Bridgeport or New Haven. Outside of the fast freights, which are usually under 1500 tons trailing weight, most of the freights are hauled by two locomotives, the trailing tonnage averaging from 2500 to 3000 tons, although, as an experiment, tests have been made in using three locomotives with trains of over 200 cars and 4500 tons trailing weight.

About 20 freight trains are hauled daily at the present time by electric locomotives between Harlem River and Bridgeport or New Haven.

Switching.

Electric switchers are used in the three main switching yards on the Harlem River Branch, located at Westchester, Oak Point, and Harlem River; likewise at Stamford, Port Chester, New Rochelle, Mt. Vernon, and at Van Nest, the latter yard being principally used for storage.

At Oak Point and Harlem River the switchers are used principally for unloading and loading floats and making up trains. One switcher was placed in service in March, 1911, at Stamford, and the remaining 15 have been in operation since September, 1912. They have been highly successful in operation, and their reliability is evidenced by the fact that to date there has been only one case of grounded main motor, although the 16 locomotives have made approximately 50,000 miles each. Some of these locomotives have been at times in continuous service 24 hours per day for 30 days, the only attention received being the renewal of blower or compressor motor brushes, or contact shoe of pantograph trolley at such times as change was made of the operating crew.

Four of these electric switchers have been found to do about the same work as six of the steam switchers, which they have displaced, principally on account of the fact that the electric switchers can be used almost continually with no layover periods. On account of the simplicity of the equipment on these locomotives, used only on A.C., compared to the more complicated equipment used on the A.C.-D.C. locomotives, no trouble has been experienced in breaking in new men, and, as a rule, the engineers need comparatively little preliminary instruction when being transferred from a steam locomotive to an electric switcher.

Mercury Rectifier Car.

For some time a motor car has been in service which has been equipped with a Westinghouse-Cooper-Hewitt mercury arc rectifier and four 250-horse-power motors. After a period of experimental runs on the Harlem River Branch, this car was placed in commercial service on the New Canaan Branch on September 16, 1914, hauling two trailers, the weight of the trailing load being 76 tons. In this service the motor car has been making an average of 240 miles per day. During the time the car has been in commercial service two delays due to failure of the equipment on the motor car have been recorded—one of three minutes on October 13, due to poor contact of a control interlock finger, and one of sixteen minutes on October 16, due to a broken belt on the circulating water pump.

In 1905, when it became necessary for the New Haven Road not only to actively consider electrification, but promptly decide upon the system to be used, as there was but a scant two years left between that time and the date set by the decree of the New York Court for all New Haven and New York Central trains to operate by power other than steam through the Park Avenue Tunnel, a careful study into the conditions surrounding the New Haven requirements pointed to the necessity of a system different in principle and arrangement to that which had been decided upon and very nearly completed by the New York Central Company—not that the New York Central Company had not made a choice of system which was entirely correct, but because the New Haven conditions were so entirely different from those of the Central. If we regard the New Haven electrification a success, here we must first note conditions that had to be reckoned with to ensure that success.

It was plain to the engineers who had studied these conditions that even in that early day, when the direct-current, 600-volt, third-rail system was at the height of its efficiency and popularity, it, when examined upon an economic basis, would fail by far in the result that would be secured in the use of the high-voltage, single-phase system.

In those days our experience with the A.C. system was *nil;* a clear vision as to the correctness of its principles, however, more than replaced this lack of experience. To many these were strange arguments to use against a well-tried-out and accepted system, and, while deeply sensible of a period both difficult and trying to the operators of the road, the burden of this decision had been made light by a willingness on the part of all to take a perspective rather than a foreshortened view of the situation as it has gradually worked its way out of its initiative troubles.

A storm of criticism from all parts of the world assailed our conclusion. As this, however, is ancient history, to say more along these lines would be to say less. This paper, however, might lack a detail not to mention the real reason for which a paper, entitled "The Log of the New Haven Electrification," presented in 1907 before the American Institute of Electrical Engineers, was written. It seemed to the writer that the thick layer of criticisms shortly after electrical operation was inaugurated, on top of the number that had been received before, required that the discussion be held down to the actual facts in the case, and, knowing that the principles upon which the New Haven electrification was based could not be assailed, and that the log sheet of operation, bad as it was, was merely a reflection of the minor details common to initiative in all new undertakings, it were best to write a paper of the faults that had appeared and the methods used for their correction. This had the desired effect, as the discussion since then has been held within the facts.

It took not a great while to determine upon and eliminate the causes incident to the failures which reflected deleteriously upon the service of the road, and, while the reliability of operation in the electrical zone rose to some three or four times that of the steam operation it replaced, it was not then or even now what it will ultimately be. At this point we touch upon one of the conditions to be satisfied in order than an electrification may be called a success; namely, reliability of service.

The replacement of a steam service which had never been criticised, by an electrical one of increased reliability, naturally brought the pronouncement of success by the public. Indeed, since those first days after the elimination of the troubles which assailed us in our initiative operation there has never been anything other than a favorable comment, both on the part of the public and the technical press. Naturally this was most encouraging to the new Haven engineers.

About two years following the presentation of " The Log of the New Haven Electrification " the writer ventured a second paper, entitled " Electrification Analyzed, and Its Practical Application to Trunk Line Roads, Inclusive of Freight and Passenger Operation," this also being under the auspices of the American Institute of Electrical Engineers, the intention being to present such electrification construction and operating data as he had collected to date, the object of the paper being to show the adaptability of electricity to extensive trunk line movement in all of its branches, covering passenger, freight, and switching on terminal and main line tracks.

In presenting the paper the writer purposely avoided a reference to comparative costs of operation between steam and electricity for two reasons: The first, because of the fact that only a part of the whole division was electrified, and an extremely expensive interchange of steam and electric operation had to be maintained, necessitating expensive duplications and special arrangements which would not have been common to either system had one or the other been used in its entirety upon the whole division. The second had reference to the matter of construction costs, which were exceedingly high in the case of the original electrification between Woodlawn and Stamford—the first undertaken. I am sure it will be of interest to state that in the original electrification the unit cost in 1907 for the four-track overhead system was just double the amount expended on the four tracks recently completed in the section between Stamford and New Haven.

In the discussions before the American Institute of Electrical Engineers and the American Society of Civil Engineers repeated requests were made for a presentation of the construction and operating costs in connection with the New Haven electrification. For the reasons above cited, and for the fact that the New Haven electrification was decidedly handicapped in being required to build its motive power equipment to operate either with alternating current or direct current, the writer concluded that the time had not arrived where a presentation of these details would serve a useful purpose. Especially was this true in the bitter war that was being waged by parties who were prone to look upon the single-phase system of traction as deterrent to the application of the " more reliable D.C. third-rail system "—then in the flower of its youth, but since gone to seed! (I, of course, have reference to trunk lines.)

Here was the problem the engineers of the New Haven Road had placed before them: the consideration of an electrification, the demands upon which would be far beyond any other hitherto constructed or contemplated. The conditions and principles applying to the past and smaller electrifications did not apply to it. Which were to control—the correct principles with the failures always common to initiative, or the wrong principles with a sureness that the service for possibly a number of years would be of a more reliable character? Some of our friends in the technical press have been good enough to say some kind things with regard to the courage of our convictions. It did not take a very great deal of courage to do the right thing, and it cannot be denied that right principles should always govern.

Naturally, ten years of almost undivided attention to electrification work have brought a better knowledge as to how power-houses, lines, locomotives, and shops should be constructed, and I do not believe I overstate when I say that the electrical plant the New Haven now possesses could be reproduced, and with far better operating results, at certainly not more than 60 per cent. of its original cost, but, notwithstanding this, when the electric division is on a 100 per cent. electrical basis the economic return will be sufficient to justify the electrical expenditure to date.

The recent decision as to choice of system on the part of the Pennsylvania Railroad in favor of single phase for the proposed electrification on its main line between Philadelphia and Paoli, this action being a forecast of the system to be employed in the event of the future financial situation permitting electrification between New York and Washington, was one of no small consequence and pleasure to those who had been toiling to establish a correct application of electrification to trunk line territory.

To those who every day had been in close association with the practical workings of this system initially installed on the New Haven, failures were too closely associated with cause and effect to suggest even disappointment, to say nothing of discouragement, but let me refer to an admirable and fine distinction as evidenced in the decision of Gibbs and Hill, which discounted apparent for real results, and settled that the body of their electrification should be upon a single-phase basis, notwithstanding that the largest terminal upon the same railroad was operated upon a direct-current basis.

I envy, indeed, the result that they should be able to produce for the Pennsylvania Company in the use of straight alternating current upon their lines. Even the record of the New York, Westchester and Boston with its straight alternating equipment, whose log sheet reports will show 125,000 miles per car failure, may be surpassed on the Paoli Division by this coming Pennsylvania electrification. As I forecast this record that should be made, I review in retrospect some of the experiences that have caused it to be possible. Among the number are generator windings that have torn themselves loose from their housings by action of 11,000-volt short circuits upon their grounded phases; sectionalizing oil switches on the line hurling their cover plates 100 feet in the air, due to these same short circuits; the overhead contact line parting company with itself, due to high-speed pantograph shoes impinging themselves against the hard spots at hanger points; locomotives nosing their way along the tracks with broken quill springs and grounded motors; and so we might go on drawing the picture of our difficulties based upon lack of experience, but the future is the brighter picture. None of the railroads, not one, will have to go through this. It is all behind us, and present operating statistics are now the proof that the high-voltage alternating-current electrification, with its attendant higher efficiency, will be as reliable as the direct-current, if not more so, on account of the simplicity of its control.

Governed by the right principles, we have passed from the days in which we desired to make it work into those in which we must make it pay. Accurate distributions of the costs in all departments of construction in their application to power-house, lines, locomotives, and shops, together with expenses incident to the maintenance and operation of these salient features since the work was first undertaken, have shown a declining curve of unit costs throughout these various details as against the progress of time. Some road had to make the first break into the dark. No one had any advice to give, as no one had any experience upon which to base it. Some of our critics have been inclined to view the New Haven electrification as a great experiment. They are right—it was; but as an experiment it has given a cleaner and more reliable ride for the public, and in the end will not cost the New Haven road a (economic) penny; but its greatest value in my estimation has not been so much this as the more stable position in which it has placed the other roads of this country to consider electrification, a subject to which they will have to address themselves in the near future.

The larger part of the experimentation is over, and, from the data assembled, future results, in the application of electricity in heavy trunk line territory, can be predicated on assembled facts, and not predicted from hypothetical analysis. Critics have had it that the so-called "battle of systems" has delayed the electrification of railroads. As an electrical engineer keenly alive to the desirability of interesting railroads in moving their trains by electricity, I am glad if any insistence on my part upon the matter of "system first" has delayed electrification in this country, and argue that every minute of the delay will be a future asset to the railroads.

When we talk about railroads we generally mean trunk lines, and all trunk lines have essentially common and determining characteristics that make the best system of power distribution for one the best for all. Therefore I count it most fortunate that electrification has been delayed. Over the same standard gauge cars of every description can be hauled. Therefore, why not a standard overhead conductor under which every form of electric motive power can operate?

I recall with interest one of the New York Railroad Club meetings, of which many have been held, typified as their "Electrical Night," at which a committee previously appointed reported its recommendations with regard to the application of alternating or direct current to specific situations. Particular stress in this report was laid in the advocacy of direct current for large terminals. This appeared to me as a fallacious conclusion, as the record of my remarks for that evening will doubtless disclose. It was clockwork typified in the movements made in these great New York Central and Pennsylvania direct-current terminal electrifications. A credit indeed was due the splendid corps of engineers who in those early days were responsible for the decision and execution of these works; yet conspicuous for their absence on this committee was that same corps of engineers, for to have subscribed to such an electrification policy would have included their concession that the tail of the dog was to wag his body! The committee made it clear that if the electrification was to be confined to terminal limits, then without question that electrification should be undertaken upon a direct-current basis. Immediately following this recommendation alternating current was prescribed as best befitting trunk lines. I well recall the hiatus from which my brain reeled as I listened to the speaker divorce the trunk line from its terminal and draw in perpetuity the picture of the one great electrical evil from which it was desirable to escape; namely, the uncongenial marriage of alternating current to direct current. Fortunately we have learned enough about this matter by experience not to fear the execution of such a policy. As evidence of this fact, one of the simplest proofs is a reference to the wonderful reliability and economy of service to which we are treated in serving the great terminal yards at Oak Point and Harlem River with the straight alternating-current switching locomotive. During the past two years, in which 16 engines of this type have been in operation and in which over 1,000,000 locomotive miles in commercial switching service have been recorded, there has been, as previously advised, just one main motor failure. This, however, is touching upon details of which we will speak later, and I have only mentioned it here in support of the argument that all motive power equipment should, if possible, be designed for operation upon one form of current, this being one of the essential conditions precedent to successful electrification.

At this juncture it is of interest to point to the fact that under the single-phase, high-potential contact wire three types of electric motive power—the single-phase, the three-phase, and the direct-current (through the medium of a rectifier)—can operate; thus each class of equipment is permitted a supply of power unchanging in form.

The principle of cardinal importance to the writer's mind, and one of the conditions affecting the success of main line electrification, may, therefore, be said to be the establishment of a standard system of power distribution, from the contact wires of which shall be delivered power in standard and unchanging form, and, while all electric locomotives or multiple-unit equipment will primarily receive this power in identical form, it may thereafter be modified or transformed to conform to any type of alternating-current or direct-current equipment, which is in turn prescribed by the local conditions. Such a standardization would provide a single high-voltage contact wire running throughout an entire electrification zone upon which are impressed 11,000 volts of 25-cycle, single-phase electricity.

Such a line could have operating beneath it single-phase equipment of the New York, New Haven and Hartford design, three-phase equipment of the Norfolk and Western design, and, finally (through the medium of the rectifier), direct-current equipment of the New York Central design, all of these equipments having entirely dissimilar torque-speed characteristics prescribed as local conditions demand. I believe that we will all admit that such a standardization offers a wonderful flexibility, but, after all this, flexibility is not the real reason for its acceptance, although we cannot fail to class it as one of the facts that form a part of a correct conclusion. The real reasons are rooted in the field of economy, where the railroad dollar must justify its investment. There is no other distribution and contact system that can touch it in efficiency. Its principles have intertwined themselves with every application of electricity in the variegated field of its usefulness, and in no place is its application more apt than in supplying power for train movement.

Up to this point the writer has possibly levied upon your indulgence in treating his subject upon very general lines, but in so doing there has not been a moment when the specific subject of the paper has not been in mind. The subject itself is such a broad one that in truth it must be said that it has been more difficult to know what not rather than what to say, and what has been said has only been in an effort to show that during this pause we have been schooling ourselves by the analysis of the data secured; sorting it into cost *versus* return; studying comparative results arising under varying conditions; crystallizing out the mistakes that have been made in the past by lack of sufficient experience and information; drawing conclusions that are not guesses on what shall be the future methods to be followed in electrification, and assembling our facts for ready reference and application.

Now, coming to the specific subject of the paper, let me point first to the great underlying condition, apart from the engineering, construction, and operating side, upon which the success of main line electrification, from a combined public and railroad standpoint, is founded: success is entirely dependent upon the *density of traffic.*

A commercially successful electrification may be described as one which, through its agency, cuts the operating expenses of steam-operated territory it has replaced to a figure whereby the savings effected are of an amount sufficient to justify the investment made.

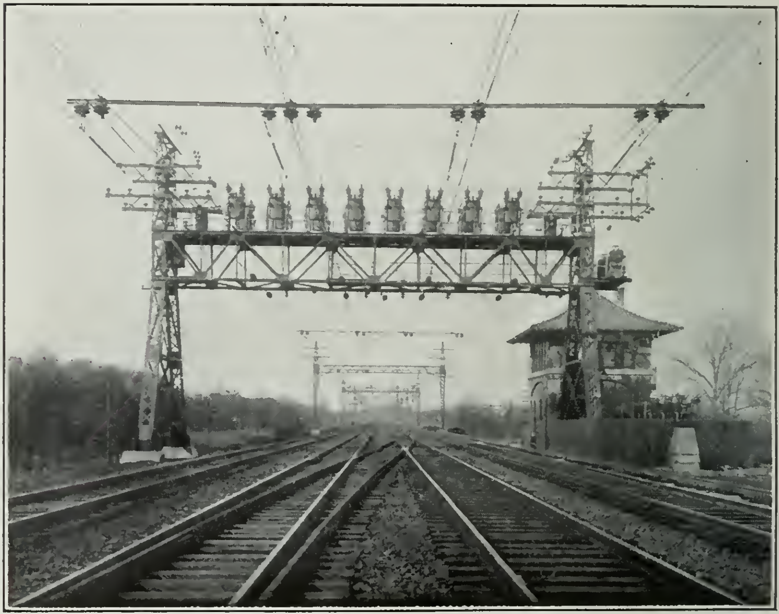
Our experience to date has taught us that electrification points to three principal places where economy of operation can be secured, and in the order of their importance they may be mentioned as follows:

1. Saving in fuel.
2. Saving in motive-power maintenance and repairs.
3. Saving in train miles.

Assets created by electrification, which may at times be controlling factors, as, for example, the reclamation of city terminal property, after the removal of gas and smoke by the elimination of steam locomotives, are of most important consideration. In cases, however, that do not involve large city terminal electrification, the general credits and debits resulting from electrification work may be said to about offset each other, and thus the value of the returns can be based upon the three items first mentioned. If we know the number of freight and passenger train miles in a division proposed for electrification, and the cost of each one of the train miles, to-day we can say with very little chance of error what the cost of each one of those train miles in freight and passenger service will be when that division is operated by electricity. If we were to duplicate the steam train movement by an electric train movement a certain economy would be shown, but by reason of the ability to concentrate in single train movements greater tractive efforts and higher speeds, greater individual tonnages can be translated, and thus the third item of economy appears in the reduction of train miles.

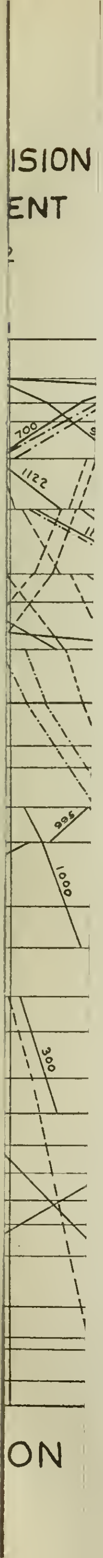
As bearing on the matter of a reduction in train miles through means of electrification, the three charts applying to studies recently made on the Salt Lake Division of the Denver and Rio Grande Railroad are interesting. In these charts it is of importance to note the great reduction in train movement secured by electrical operation, in combination with the reduction of a section of high grade from 4 per cent. to 2 per cent. for increases of 20 per cent. and 100 per cent. in excess of the former tonnage. The example offered is merely illustrative of this application of economy under conditions of electrification.

FIG. 1.



Four-track tangent compound catenary construction, showing anchor bridge in the immediate foreground, with sectionalizing switches installed thereon. Signal tower is seen at the right of the tracks, and from this tower sectionalizing switches are controlled. Note also crossover under anchor bridge, with its overhead contact wire.

Experience with the movement of billions of ton miles in freight, passenger, and switching service by electricity has justi-



ıe
d
ın
ic
a
e;

nd
ım
ıs.
ım

ɔ-
er
al
fi-
ɔf
d,
ve
ɔe
re

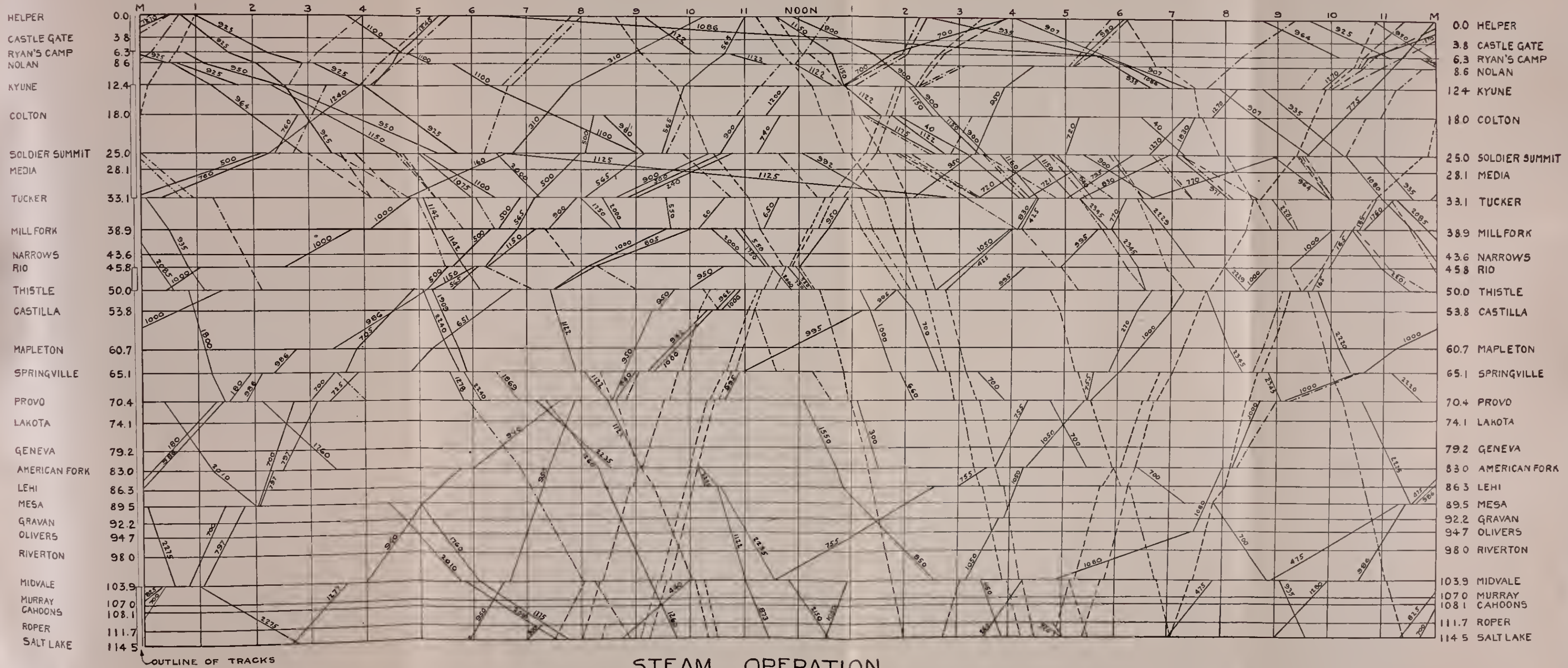
SALT LAKE DIVISION
TRAIN MOVEMENT

OCTOBER 17th 1912

- LEGEND

PASSENGER ---- FREIGHT ——— LIGHT ENGINE —·—·—
NUMBERS SHOW TONNAGE HAULED.

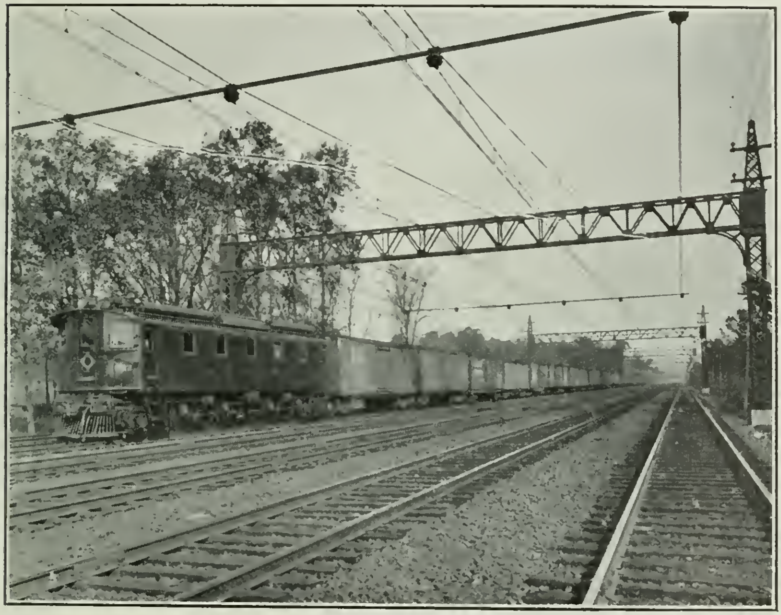
TONNAGE OUT OF HELPER 10767, TONNAGE INTO HELPER 5035.
" " " SALTLAKE 8757, " " SALTLAKE 12848.



STEAM OPERATION

fied the early predictions that were made in connection with the study of the New Haven electrification; namely, that one pound of coal burned under the boilers of a central electric power station and converted into electrical energy and transmitted to an electric engine will develop twice the drawbar pull at the same speed as a similar pound of coal burned in the firebox of a steam locomotive; and, second, that the maintenance and repairs on electric locomotives of the straight alternating-current type are on the order of one-half of those required for steam locomotives of equal weight on drivers. It is thus seen that the problem of electrification merely revolves around the question of the density of traffic in which the economies aforesaid can be practised, and, therefore, the denser the traffic the greater the requisite motive power for its movement, and hence the greater the saving to be effected. If the schedule of train movement for all roads were

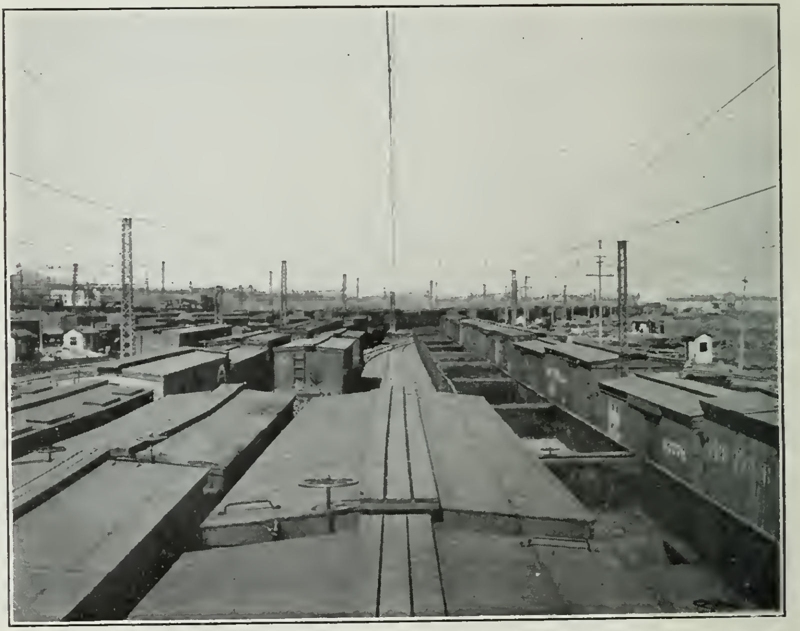
FIG. 2.



Six-track tangent compound catenary construction, showing electric freight locomotive and train. Freight trains are operated between Harlem River and New Haven, the normal maximum tonnage of which may be, with double locomotive and multiple-unit control, up to 3150 tons. The introduction of freight hauled by electricity has permitted the division to increase the steam tonnage rating twice, reduce time by 33 per cent. and train crew expenses to one-half.

the same, then, based upon the number of tons translated, it would be a simple matter to plot a chart which would show two intersecting curves, one of which represented the savings per annum to be effected by the substitution of electricity for steam, the other the summated cost per annum of interest, depreciation, maintenance, insurance and taxes on the electrical plant, inclusive of power-house, lines, locomotives, and shops, necessary to effect these savings, these curves having as common abscissa tons under translation and as ordinates the annual costs respectively represented in the foregoing classes of annual expenditures. The point of intersection of these curves would indicate the density of traffic at which the economic yield of electrification would cover the fixed charges incident to its installation. The curves would also indicate the yield to the railroad that electrification would bring above that of steam operation for traffic densities of greater

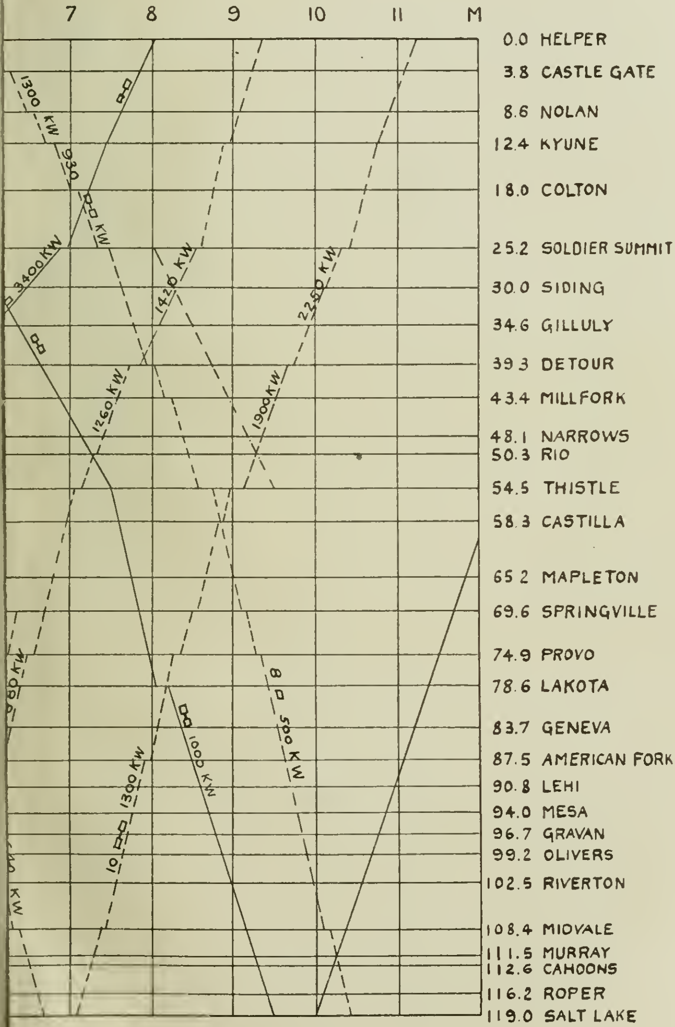
FIG. 3.



View in Westchester Yard, Harlem River Branch, showing overhead construction used in electrifying large yards. The cross catenary span in the immediate foreground serves ten tracks. In the case of the Harlem River Yard there are single spans serving eighteen tracks. For equal electrical energy delivered, the cost of this construction is one-third that of the third-rail.

GENERAL DATA

WESTWARD HELPER TO SOLDIER SUMMIT 16.000 TONS DAILY
" SOLDIER SUMMIT TO SALT LAKE 15.000 " "
EASTWARD SALT LAKE TO HELPER 9.000 " "
F PASSENGER COACHES WESTWARD 30
" " " EASTWARD 36
" TRAIN MILES WESTWARD 1217.2
" " " EASTWARD 1141 6



KEY TO FREIGHT TRAIN MOVEMENTS

BETWEEN	WESTWARD				EASTWARD			
	NUMBER OF TRAINS	SPEED M.P.H	TONS PER TRAIN	NUMBER OF LOCO.	NUMBER OF TRAINS	SPEED M.PH.	TONS PER TRAIN	NUMBER OF LOCO.
HELPER-KYUNE	8	12.5	2.000	○○ □□	5	20	1.800	□□
KYUNE-SOLDIER SUMMIT	8	23	2 000	□□	5	35	1 800	□□
SOLDIER SUMMIT-DETOUR	5	20	3.000	□□	5	14	1 800	○○ □□
DETOUR-THISTLE	5	20	3.000	□□	5	17	1 800	○○ □□
THISTLE-SALT LAKE	5	35	3 000	□□	5	31	1 800	□□

SALT LAKE DIVISION
TRAIN MOVEMENT

CHART #1; 20% INCREASE IN TONNAGE OVER CHART OF OCTOBER 17th 1912.

-LEGEND-

- - - - - PASSENGER, ———— FREIGHT, — — — LIGHT ENGINE

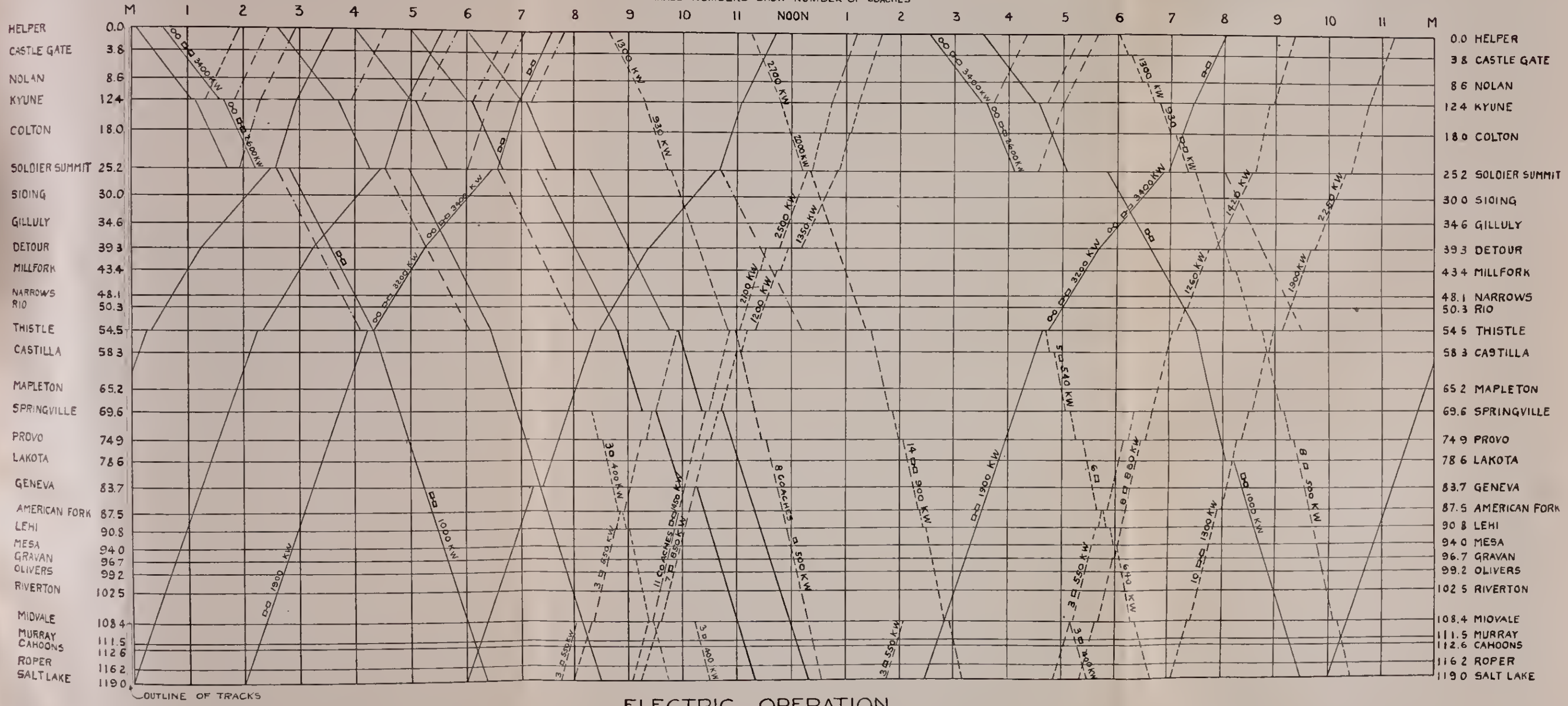
○ PUSHER LOCO., □ COMBINATION LOCO

○○ & □□ INDICATES TWO LOCO. OPERATED AS ONE UNIT

SMALL NUMBERS SHOW NUMBER OF COACHES

GENERAL DATA

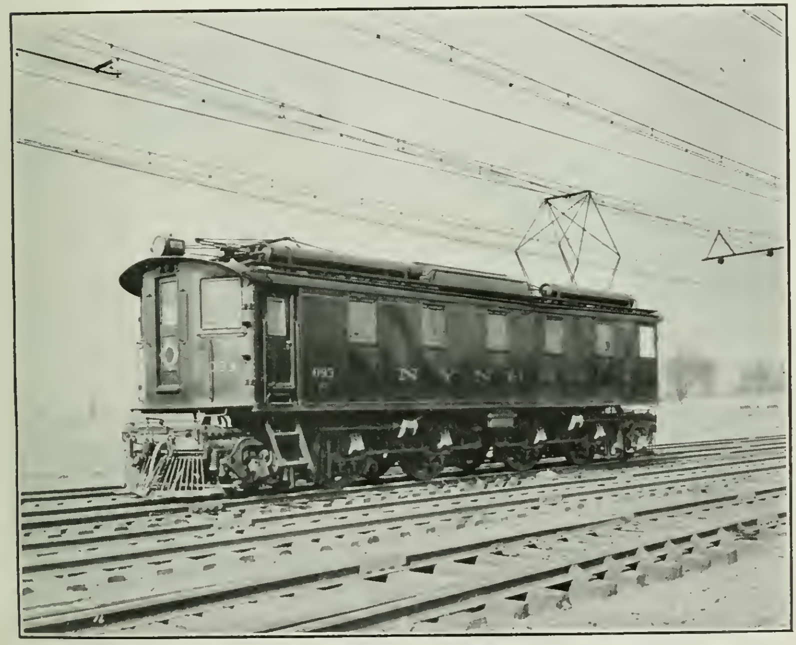
TOTAL TONNAGE WESTWARD HELPER TO SOLDIER SUMMIT 16000 TONS DAILY
" " " SOLDIER SUMMIT TO SALT LAKE 15.000 " "
" " EASTWARD SALT LAKE TO HELPER 9.000 " "
" NUMBER OF PASSENGER COACHES WESTWARD 30
" " " " " EASTWARD 36
" " " TRAIN MILES WESTWARD 1217.2
" " " " " EASTWARD 1141 6



ELECTRIC OPERATION

amount. The analysis, however, is not as simple as this, for, while a number of roads might translate equal tonnages over equal distances, the local conditions might require a wide variation as to schedule; also such physical adjuncts as grade and cost of electric power supply, labor and material clearly make it necessary to give careful consideration to each individual case. The point which I wish to make, however, is that, with knowledge based on experience, operating officials of railroad companies can have an intelligent presentation made to them of the comparative cost relation between steam and electric operation for these several roads. An intimate acquaintance with the ways and methods of the steam railroads of to-day has taught us how the president, the vice-president, the general manager, the general superintendent, the mechanical superintendent, the division superintendent, the

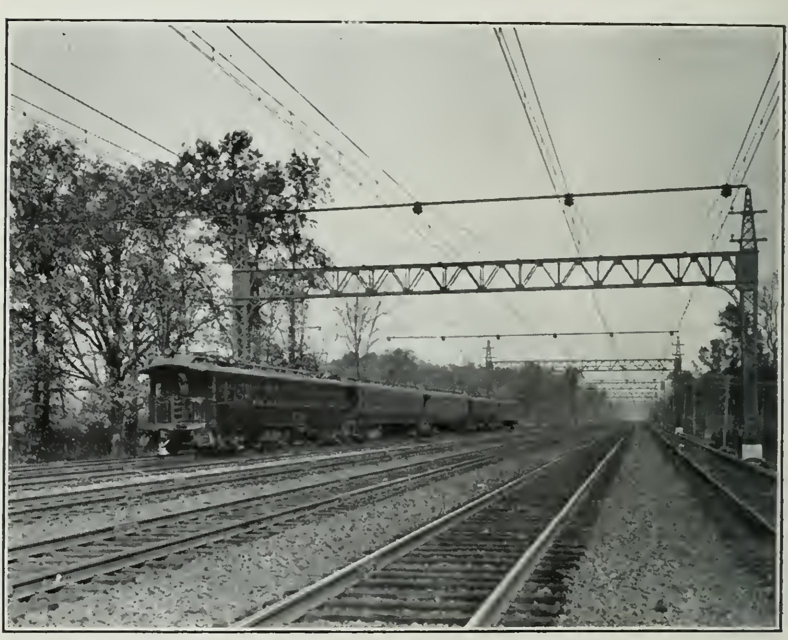
FIG. 4.



Standard straight alternating-current freight locomotive capable of handling 1500 tons at 35 miles per hour continuously. Weighs 110 tons, 80 per cent. of which is on drivers; develops a maximum tractive effort of 40,000 pounds, and will maintain a tractive effort of 12,000 pounds continuously. The rated continuous capacity of this electric engine is 1400 horse-power. The overhead contact shoe receives a potential of 10,000 volts, which is transformed to 600 volts and in turn is delivered to the terminals of four twin motor equipments in parallel, each motor on the twin combination receiving a maximum normal potential of 300 volts.

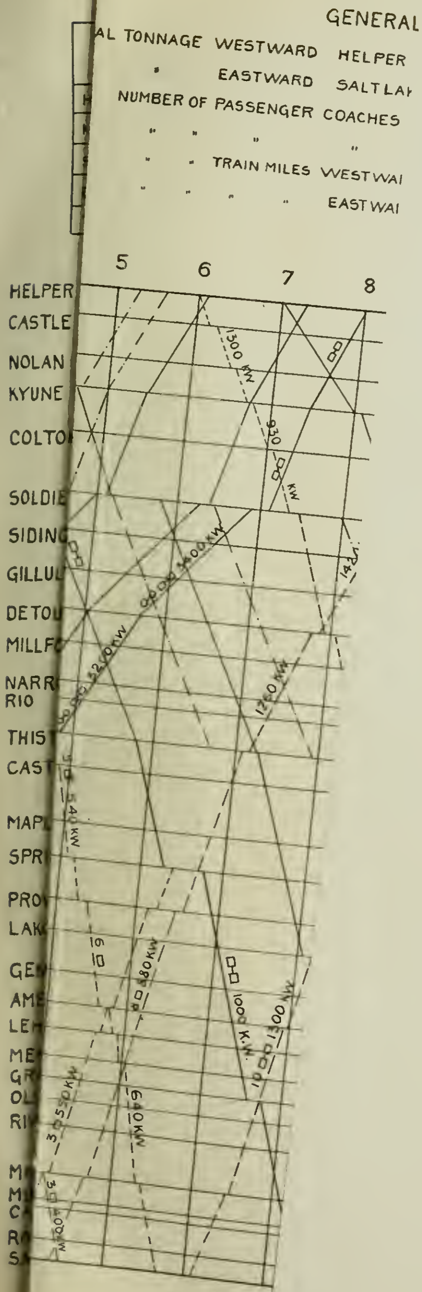
master mechanics, the road foremen of engines, the shop superintendent, and so on down the line to the engineers whose hands are on either the levers of the steam or electric engines, look at operation. Seven years of parallel steam and electric operation on the same division have opened up a world of perspective to the writer, as he has studied the controlling forces which whirl through the beginnings of this conversion from steam to electricity in the trunk line territory of our American railways.

FIG. 5.



Multiple-unit train operating on six-track Harlem River Branch electrification. This multiple-unit train is also designed for operation on the New York Central direct-current third-rail system. Each motor car has sufficient capacity to haul itself and two trailers.

I would count it a serious omission indeed did I not mention the great and able assistance the present general manager of the New Haven Road, Mr. C. L. Bardo, has given in his study of the operating side of this great electrical problem. It is of him that I think when I touch upon one of the essentially real conditions affecting the success of main line electrification, and that is in the matter of administration. Electricity as an agent of power development is as essentially different from steam as the effects which are produced in the application of heat or cold. The steam



ıot a
es of
hav-
great
n of
reas-
our

Four of
ns, with
ll main-
es have
ure, due
iance to

-day.
omo-
h the

epairs
steam
, and
to the

KEY TO FREIGHT TRAIN MOVEMENTS

BETWEEN	WESTWARD				EASTWARD			
	NUMBER OF TRAINS	SPEED M.P.H	TONS PER TRAIN	NUMBER OF LOCO	NUMBER OF TRAINS	SPEED M.P.H	TONS PER TRAIN	NUMBER OF LOCO.
HELPER-KYUNE	15	12.5	2 000	o-o□-□	10	20	1 800	□-□
KYUNE-SOLDIER SUMMIT	15	23.0	2 000	□-□	10	35	1 800	□-□
SOLDIER SUMMIT-DETOUR	10	20.0	3.000	□-□	10	14	1 800	o-o □-□
DETOUR-THISTLE	10	20 0	3 000	□-□	10	17	1800	o-o □-□
THISTLE-SALTLAKE	10	35 0	3.000	□-□	10	31	1.800	□-□

SALT LAKE DIVISION
TRAIN MOVEMENT

CHART ⁿ2; 100% INCRESE IN TONNAGE OVER CHART ⁿ1

-LEGEND-

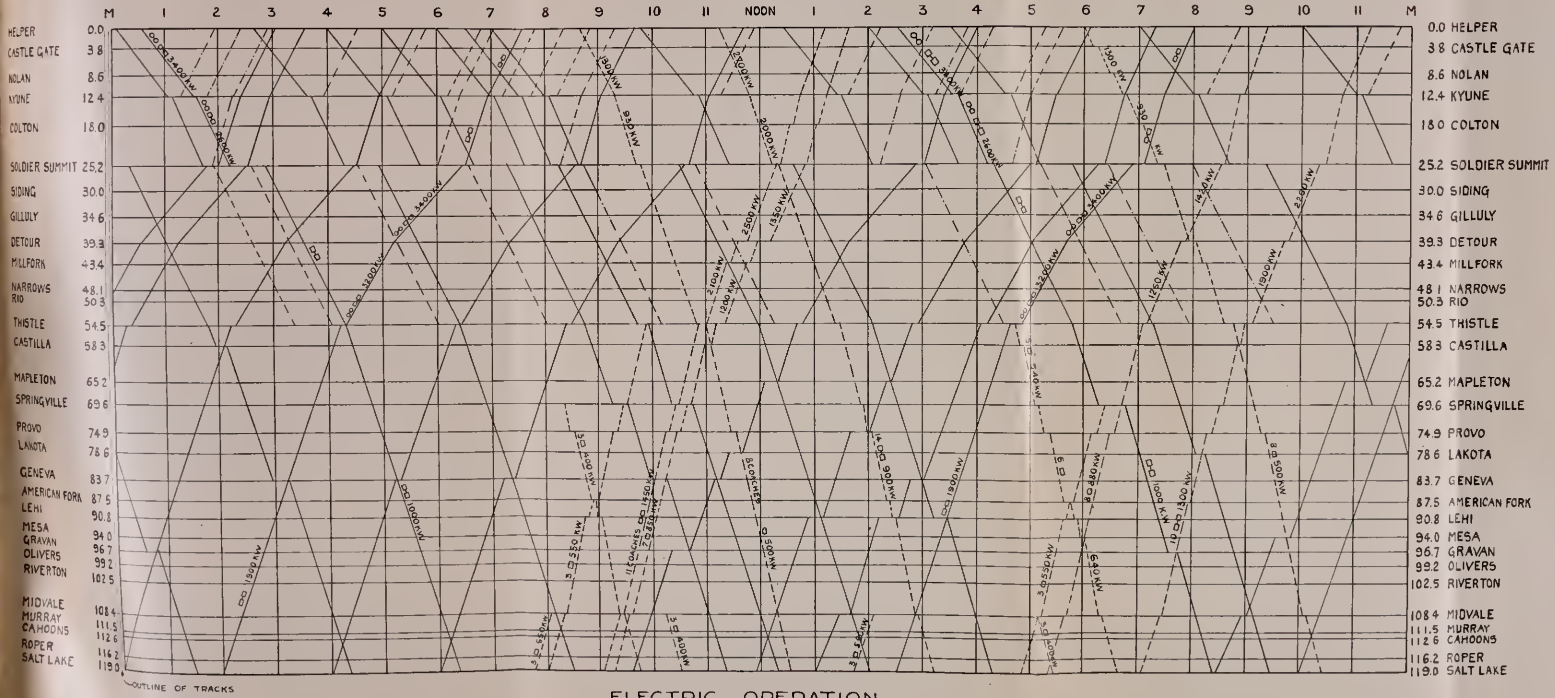
– – – – PASSENGER ———— FREIGHT —·—·— LIGHT ENGINE

o PUSHER LOCO., □ COMBINATION LOCO.

o-o & □-□ INDICATES TWO LOCO. OPERATED AS ONE UNIT.
SMALL NUMBERS SHOW NUMBER OF COACHES.

GENERAL DATA

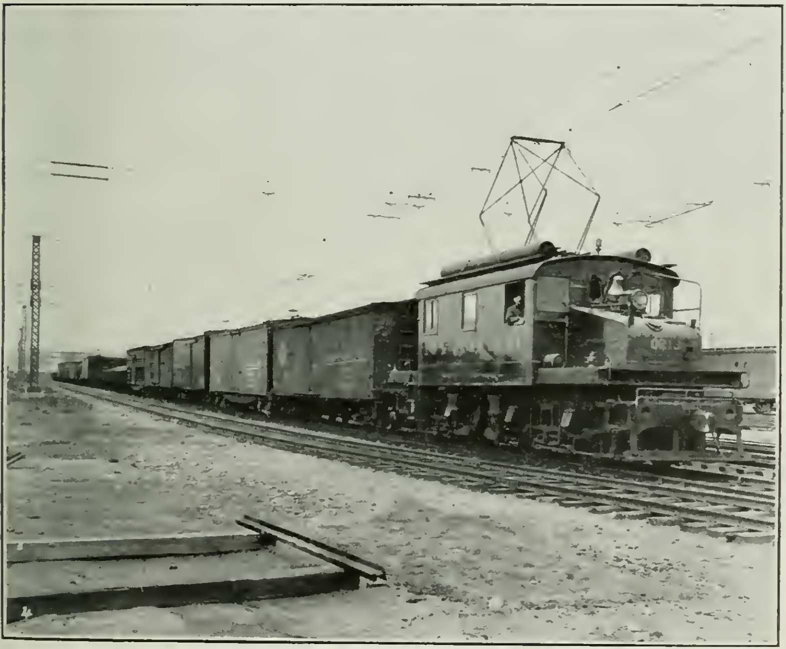
TOTAL TONNAGE WESTWARD HELPER TO SALT LAKE 30.000 TONS DAILY
" " EASTWARD SALT LAKE TO HELPER 18.000 " "
" NUMBER OF PASSENGER COACHES WESTWARD 30
" " " " " EASTWARD 36
" " " TRAIN MILES WESTWARD 1862 6
" " " " " EASTWARD 1736 6



ELECTRIC OPERATION

locomotive has lived a useful life of eighty years. This is not a prediction that it will not live many more! Even in the clothes of its mechanical ruggedness it is not difficult to conceive of its having once been a pretty delicate machine, deserving of a very great deal of care and attention. The electric locomotive was born of even a more delicate nature, and, while its ruggedness is increasing, it can never possibly be the great mechanical brute that our high-powered steam locomotives may be typified as being to-day. In the same breath, however, it may be said that the steam locomotive can never reach into the zones of usefulness to which the electric engine can at the present day enter.

FIG. 6.



Electric switcher No. 0213, doing regular switching service in Oak Point Yard. Four of these engines are capable of doing the work of six steam switchers. They weigh 80 tons, with 100 per cent. weight on drivers. They will develop 40,000 pounds tractive effort, and will maintain a tractive effort of 12,000 pounds continuously. Sixteen of these electric engines have recorded over 1,200,000 miles in switching service, and one failure, a burned-out armature, due to a prolonged and excessive load from brakes sticking, is the record of their performance to date.

It is perfectly possible to keep the maintenance and repairs of the electric locomotive down to one-half of those of steam under the most favorable conditions of steam maintenance, and in many cases below this figure. On the other hand, due to the peculiar nature of the electric engine, which has not as yet been enough appreciated, it will be only by the most rigorous and careful inspection and conformity to rules of operation that this relation can be maintained. Indeed, if electric engines be treated as has been the custom of treating steam locomotives, then their repairs, instead of costing far less, will cost far more than those of the steam engine. The essential difference between the steam and the electric engine is that the former, after it has done all the work it is capable of doing, will lie down, simply stop going, and do this at no cost to its mechanical parts, while an electric engine, like an overwilling horse, if permitted, will work itself to destruction. The commercial life and efficiency of a steam engine may be said to depend on keeping the heat within its cylinder walls, while the commercial life and efficiency of the electric locomotive are based on how cool you can keep its conductors. In the vernacular of the American youth, some difference! Yet, if you ask the old steam superintendent operating the new electric division if he agreed to that distinction, the chances are he would say: "Sure, the conductors should never get hot, especially with a passenger." Mr. Bardo has recognized this great difference between steam and electric operation, and in handling the schedule of electric trains he has emphasized the importance of keeping the train loads down to a point within the safe temperatures of the electric motors performing the schedule. The days are passing when with pride the steam operating man points to the electric locomotive as having been able to perform twice the duty for which it was designed, and the next day wondering why the darned old "electric" blew up on half the load. The point to be established, therefore, is that successful electrification requires that there be in the administrative forces minds trained to the necessity of a different viewpoint from that which has come down through these eighty years of steam service. The magnificent organization that has shaped itself throughout these many years and has standardized itself, one might say, in its application to all roads, need not in any way have its fabrics torn or changed by the introduction of electricity as a motive power, but there must be established in the administrative forces different minds from those in the past to handle these different things of the future. The future must see well-developed electrical cells in the minds of the vice-presidents, general managers, general superintendents, etc., down the line.

An inheritance by the New Haven of the old steam locomotive engineers for the operation of their electric engines is another case where the tail of the dog wags the body. While it is a good argument that these men understand the roadbed and signals better than any one else, this argument fails when engineers without electrical experience or training can bid in the electric runs, depending upon their seniority and record of service. The condition might be alleviated by one set of men, once in remaining in, but there is a constant change, and it is a long time before the steam locomotive engineer divorces himself from the fact that he is not operating a steam locomotive. During his period of learning how to operate the electric engine he does not suffer, the people do not suffer, but the road suffers, and the locomotive suffers most. Here, therefore, we see the necessity of electrically trained men. The very logic of this stand will ultimately require that these things be so, and one of the successes of which we write in this paper is based upon it being made so.

While all of the main line tracks of the New York Division are electrified, there still remains in passenger and freight service, as previously shown, a considerable amount of steam operation, made necessary by the New Haven Road having had to avoid capital expenditure for power-house and motive power equipment. It can be readily understood that a large reduction in operating expense can be effected when the division is placed upon a 100 per cent. electrical basis. On previous occasions when the writer has been dealing with statistics and information made available by his engineering and operating association with the work he was conscious then, and is now, of the danger, in presenting construction and operating costs, of their possible misinterpretation.

Essentially necessary is a wholesome confidence on the part of railroads undertaking electrification that the result predicted will be attained, and what we are doing on the New Haven to-day electrically from an operating standpoint could not be better epitomized than by the presentation of one of the last monthly operating reports. They follow, and are known as the statistics of electrical operation, and give operating information with reference to:

1. The amount, distribution and cost of electric power generated at Cos Cob Station.
2. Statistics and operating costs of electric passenger service.

3. Statistics and operating costs of electric freight service.
4. Statistics covering line and equipment failures.

These records are included in this paper not as an exhibit of something remarkable, but simply to convey to those interested in the electrification of railways the fact that there is daily coming to us a mass of data having reference to the practice of heavy electric transportation, through the agency of which very accurate conclusions may be drawn.

I would ask those who review these statistics with an analytical eye to bear in mind that they are taken from an electrical plant which, from its inception, has been handicapped both from a construction and operating point of view. As before explained, the underlying principle applying to the New Haven electrification required that its motive power equipment be designed to operate on both alternating- and direct-current power, and that, further, on account of inadequate shop facilities in the past it has been necessary, since securing new shop facilities, to make very heavy repairs throughout the entire electric motive power of the road. I have, therefore, to offer this word of caution in analyzing the statistics that are presented, for it is to be noted that the cost of locomotive repairs is high. For example, referring specifically to the table of operating costs of electric passenger engines (page 552), it is to be noted that in the month of October the repairs are recorded as 8.56 cents per locomotive mile, while for November these repairs have increased to 10.61 cents per locomotive mile. At the first blush this would indicate that the new shop facilities were increasing rather than diminishing maintenance costs. This, however, may be explained by the fact that all of the passenger engines have been undergoing general repairs, and invoices for material were passed in greater amounts for November than for October. Many of the electric locomotives have not received a general overhauling since 1907, and during this time their log sheets of operation show some of the locomotives have made over 350,000 miles.

Showing conclusively, however, what can be done with electrical equipment under the care of a better maintenance, I have taken the first ten engines that have received general repairs and present herewith in the following ten tables segregated monthly costs and mileages made since these engines have passed through the shops.

Notwithstanding these engines are of the alternating current-direct current type, it is of interest to note that their records so far show an average cost of under five cents per locomotive mile. It is of particular interest to note that locomotive No. 032, which received its overhaul first, has now operated 93,140 miles at an average cost of 3.6 cents per locomotive mile.

These maintenance figures for the ten engines give a sharp contrast to those in the general table of passenger engine operating costs (p. 552) and emphasize the lack of maintenance to which the electric locomotives were subjected in the early days of their operation. Had conditions permitted our electric passenger engines to be of the straight alternating-current design, in my opinion their average maintenance would not have exceeded .4 cents per locomotive mile.

During the past six years of electric operation there have been collected some very valuable data with regard to the amount of power required to operate trains of variable tonnage in passenger, freight, and switching service. Based upon this data, the power required to operate trains under normal or peak conditions of schedule can be calculated with results practically coinciding with the estimates

By means of wattmeters installed on all locomotives and motor cars it has been possible to record the differences of power required by trains operating under local and express conditions. The long period over which these statistics were kept and power rate constants thus developed has permitted us to abandon an elaborate tabulation and consolidate the information in the more general statement (pp. 547 and 548). Of value to those who are interested to follow more closely these results, Tables 11, 12, and 13 will be of assistance. These tables are compiled from the June, 1914, statistics of electric passenger and freight train operation between Woodlawn and points east to New Haven. At that time the overhead system had only recently been completed to New Haven, and there was but a small percentage of electric service, both as regards passenger and freight, between Woodlawn and New Haven, and, while the tonnage in both passenger and freight service has been greatly increased since that time, these tables, however, may be taken as giving reliable data in connection with the electric train movements recorded. The watt hours per ton mile (abbreviated in tables as W.H.P.T.M.) are secured through meters recording input power to the electric motors. To determine the actual amount of power taken from the contact wire, these figures should be divided by 97 per cent., thus allowing an average loss of 3 per cent. for the step-down transformers installed on the electric engines and motive power. As examples of the increments of electric service, since the extension of the electrification to New Haven, while it is to be noted that the total electric passenger ton miles for June, 1914, were approximately 41,000,000 and that of the freight 9,400,000, the former has now increased to 62,000,000 and the latter to 44,000,000.

Of especial interest to the writer with regard to the tables covering electric passenger operation is the variation in watt hours per ton mile for the various express and local services. For example, it is to be noted that the power rate for New Haven express trains eastbound is 31.4 watt hours per ton mile, this rate being increased slightly for trains operating to Stamford; the rate rises quite rapidly for trains operating in local service to Stamford, and continues to rise for local trains operating to Port Chester and New Rochelle respectively. It is, of course, well known that the rate of power supply per ton for express operation is very much lower than that required for local operation, as in the case of the latter the train suffers, under the conditions of braking, the loss of the kinetic energy stored in it under the conditions of acceleration. The increasing watt hours per ton mile as shown in the tables are practically proportional to the diminishing distance between train stops. It may also be said that the distance between stops increases progressively east of New York City, and if, for example, suburban territory under consideration for electrification has to be served by train schedule with distances between stations approximately the same as those obtaining on the New Haven Road, the " power rate " constants as shown in these tables will be found to be sufficiently accurate in the study of power necessary to train movement.

In the tabulated statistics covering electric freight operation the point of principal interest is the difference between the rate per ton mile as indicated in the June tabulation as against those shown under the general tabulation of freight service (pp. 554 and 555), where it is to be noted that the kilowatt hours for fast and slow freight are, on the average, considerably below 30 watt hours per ton mile, this rate being based upon the tonnage of the trailing load. Allowing for the weight of the electric engine, the watt hours per ton mile will be reduced to 26, and, as some 200,000,000 ton miles have been actually recorded by meter registration in freight service, it may be said that 30 watt hours per ton mile on level track is a reliable figure, with slight margin to cover electric freight operation in a combination of fast and slow service; *i.e.,* without stops for trains averaging between 1500 and 3000 tons trailing load.

It is of interest at this juncture to point to an interesting experience we have had in connection with the electrical operation of heavy freight trains. It was first thought that when these large train units were placed on the line the power-house would be subjected to very heavy drafts of power under conditions of accelerating them. The reverse, however, was found to be the case, and where, previous to the operation of these trains, the power station output curve showed peaks of a fluctuating character, these heavy trains have served to smooth out the curve of power station output. A reasonable explanation of this would seem to rest in the fact that when a number of the heavy trains are under translation, and it becomes necessary to accelerate one from rest, the supply of current necessary to this acceleration, while not reducing the line voltage materially, does so, however, to a point which corresponds to a speed of the trains in translation lower than the speed at which they are actually operating, and thus these heavy trains, by their own mass energy, as in the case of a flywheel, automatically release a large amount of power, which becomes available for the accelerating train.

In the foregoing pages I have confined myself to the presentation of operating data, from which I believe very accurate conclusions can be drawn, having regard to the costs incident to electric operation, the only expenses that are materially changed in the conduct of railway transportation being, as previously stated, in the matter of fuel, engine repairs, and train miles. With definite information developed as to these items, it is not a difficult matter for those experienced with their application to interpolate them into the steam operating accounts in the study of railroads considering electrification. I have thought, therefore, that the broader manner of handling this subject would be not to show concrete cases where the conditions were such as to insure the success of electrification, but rather present the constants of economy that were generally applicable, at least very approximately so, to all railway situations, granting, of course, that each individual study would have its qualifying factors which local conditions would control; as, for example, it is quite possible for a complete electrification to turn upon the cost of coal. The greater the cost of coal the stronger is the argument for electrification from the fuel aspect. For example, if two railroads, one burning \$2.50 coal and the other burning \$5 coal, should electrify, and in each case reduce their coal consumption by 100,000 tons per year, they would respectively save \$250,000 and \$500,000 per annum. In the case of the railroad burning the \$2.50 coal this saving would, at 5 per cent., represent capitalized values amounting to \$5,000,000, while in the case of the railroad burning the \$5 coal the capitalized values would be \$10,000,000. In both cases the capitalized values should be credited against the construction account for electrification.

The matter of savings to be effected in engine repairs is likewise subject to local conditions, for, while it may be said that steam locomotive repairs, upon an average, may be placed at 10 cents per locomotive mile, on the other hand there may be situations where the railroad has, for example, to use water of severe scaling characteristics and thus run up the cost of repairs excessively.

In the matter of train miles the savings to be effected are dependent upon local conditions, but it can be stated as a general conclusion, based on a very considerable experience, that:

1. Electric engines on the order of 100 tons on drivers should be maintained at a rate not exceeding 5 cents per locomotive mile.
2. The coal bill for transportation is cut to at least one-half.

Having determined for any situation what savings can be effected by the substitution of electricity for steam, then, as previously stated, the commercial justification of a change to the new motive power is entirely based upon whether these savings will cover the interest, insurance, depreciation, and taxes on the electrical investment necessary.

In past papers I have refrained from presenting construction costs to show what investment is necessary to operate trunk line territory by electricity, and I believe that this policy will be accepted as having been justified in advising that an analysis of the distribution account of our latest line construction (between Stamford and New Haven) shows its unit costs (four-track) to have been one-half of that incurred in the original work, and.

while further economies will, of course, follow, I feel that the curve of decreasing electrical investment for electrification has flattened at least enough to present Tables 14, 15, and 16, which follow, indicating the costs incident to six-track, four-track, two-track, compound and single catenary for curves and tangent construction as a guide to what can be done. To those considering these figures I would offer a word of suggestion that the overhead system of the New Haven Road was designed to coördinate with a roadbed which is the throat of the entire eastern New England traffic. Very high safety factors have been included in it, both as regards wire and steel, and it has been many times, particularly during the last season, subjected to high wind velocities, the effects of which have been augmented by ice formation, increasing its projected area.

A general factor of safety of three is prevalent throughout the whole construction, whether on the 200-foot river transmission towers with 800-foot spans or on the regular catenary construction, in each instance based on ice coatings of ½ inch all around, with wind velocity of 60 miles an hour. I might add, also, that we have been fortunate enough not to have lost a wire due to the above causes throughout the history of the electrification.

Briefly referring to the tables of construction costs, it is to be noted that the supporting steel bridges have a normal spacing of 300 feet, the trusses of which are designed to withstand the breakage of any of the main supporting messenger wires, and permit also the support at any point of four signals of 2000 pounds in weight each.

As local conditions make different requirements for sectionalization, construction costs are given for continuous catenary construction for tangent and curved track, and, to facilitate the introduction of sectionalizing costs, individual figures for anchor bridge and control sectionalization are given under tables showing costs varying for the different number of tracks under consideration.

Electrification, like everything else, under effects of standardization gets down to a pound or foot basis; the costs tabulated for the different types of construction, sectionalization and control may be combined to determine total estimates on work conforming to the requirements of the local conditions.

With regard to electric motive power equipment, papers that have preceded this one have discussed in detail physical dimension, weight, and operating characteristics of electric passenger, freight, and switching engines and multiple-unit motor cars. The motive power feature of electrification, like its other parts, has virtually reached the pound stage. Electric locomotives of approximately 100 tons will, under present conditions of cost of labor and material, vary between 18 cents and 20 cents per pound. This figure is practically irrespective of speed-torque characteristics, a high-speed passenger locomotive and a low-speed switcher not varying greatly in cost upon a pound basis. Multiple-unit cars, now usually built of steel, do not vary greatly from the above figures, but, if anything, may be quoted as being slightly higher in cost per pound.

The determining characteristics of the locomotives to be purchased in an electrification will, of course, entirely depend upon the local conditions which control the maximum and continuous tractive efforts in passenger and freight service, they in turn depending upon the weight of trains and length of grades, capacity of equipment depending likewise on the two foregoing factors and schedule requirements.

The above approximate quotations on engine costs are presented merely to give a general idea of this department of expense in connection with electrification. As a concrete example in application of the above general statements, I would say that a first-class, high-speed, 100-ton, straight alternating-current electric passenger locomotive, capable of handling a 250-ton trailing load in normal large city suburban service, should cost $40,000. A steam locomotive which would do the same work would probably not cost more than $15,000, but the savings effected due to the greater operating economy of the electric engine would represent a figure of twice or three times the amount invested in the electric engine. Thus we might say that for every electric engine we purchase we would be justified at least in making a capital investment of $40,000 to cover the cost of electric power-houses and transmission equipment necessary to supply that electric engine with current. By this reasoning we again approach the answer as to the conditions affecting the success of main line electrification in the fact that it is the density of traffic and in the use of a large number of electric engines by which we can save enough money to pay for the capital expenditure necessary to the supply of power to them for the operation of many trains.

Of late many interesting and valuable papers on electrification have been written, wherein the authors have presented comparable data as between steam and electric operation on specific territory under contemplation.

As mentioned in the earlier pages of the paper, there are many places where electrification would bring a betterment both to the public and to the railroad, but the writer has thought the subject would be better served by a general exposition of his operating and construction experience in connection with a heavy trunk line electrification that has been serving the public for the past eight years, and to draw from it the significant facts and factors from which basic conclusions can be drawn to apply elsewhere.

In concluding the paper I would plead for an especially conservative point of view on the part of the public with regard to electrification. While the savings to be effected under certain conditions of electrification may be considerable, on the other hand the construction investment necessary to these savings may be very great. So many roads in this country have either passed or lowered their dividends, the chief example of which being a part of the great Pennsylvania system, that it is hardly necessary to emphasize the fact that only a healthy condition of finance throughout the country will warrant the consideration of electrification, and again I would say that partial electrification, such as that applying to yards only and not main line, while it might prove of advantage to a public, might at the same time prove to be a serious and unfair burden for the railroad to carry.

The Public Service Commissions are as much the guardians of the railroads as the people they serve, and the many billions in dollars representing the shrinkage in value of railroad securities in the last few years have awakened in the hearts and minds of the public and the commissioners the fact that no further obligations can be imposed upon the railroads, except that they be justified from a fair railroad business standpoint, such equity of treatment describing the duty of the commissioners in whose hands rests the justice of any demand. The electrification of great railroad terminals in particular presents conditions in which the maximum cost is combined with the minimum direct return upon the invested capital, and without some reasonable assurance of adequate return it will be more difficult to secure the necessary capital for such improvements.

TABLE 1.

PERFORMANCE OF N. Y., N. H. AND H. R. R. ELECTRIC PASSENGER LOCOMOTIVE 032.

	1913					
	July	Aug.	Sept.	Oct.	Nov.	Dec.
Labor	32.90	83.01	61.59	23.67	20.18	89.17
Material	20.68	38.61	67.96	21.64	34.56	104.86
Total labor and material	53.58	121.62	129.55	45.31	54.74	194.03
Mileage	4802	5517	4695	4716	4687	4592
Cost per mile	.011	.022	.028	.010	.012	.042
Average cost per mile	.011	.017	.020	.018	.017	.021
Total miles to date	4,802	10,319	15,014	19,730	24,418	29,005

	1914					
	Jan.	Feb.	Mar.	April	May	June
Labor	200.97	85.94	36.52	65.42	91.01	70.70
Material	95.79	27.12	29.15	32.57	70.01	90.28
Total labor and material	296.76	113.06	65.67	97.99	161.02	160.98
Mileage	4,392	6,017	5,310	5,270	5,889	5,839
Cost per mile	.068	.019	.012	.019	.027	.028
Average cost per mile	.027	.026	.024	.024	.024	.024
Total miles to date	33,397	39,414	44,724	49,995	55,884	61,723

	1914					
	July	Aug.	Sept.	Oct.	Nov.	Dec.
Labor	212.36	74.45	147.53	219.47	55.25	.....
Material	131.49	156.72	173.96	780.92	146.09*	.....
Total labor and material	343.85	231.17	321.49	1000.39	90.84*	.....
Mileage	6,165	7,401	5,459	5,678	6,714	.....
Cost per mile	.056	.031	.058	.176	0	.....
Average cost per mile	.027	.027	.030	.039	.036	.....
Total miles to date	67,888	75,289	80,748	86,426	93,140	.....

NOTE.—Cost in dollars. * Cr.

TABLE 2.

PERFORMANCE OF N. Y., N. H. AND H. R. R. ELECTRIC PASSENGER LOCOMOTIVE 041.

	1914					
	June	July	Aug.	Sept.	Oct.	Nov.
Labor	17.15	72.04	169.91	113.51	105.56	195.78
Material	8.92	78.24	362.15	288.68	32.29*	473.13
Total labor and material	26.07	150.28	532.06	402.19	73.27	668.91
Mileage	2,912	7,974	8,031	5,990	6,096	5,965
Cost per mile	.009	.018	.066	.067	.012	.112
Average cost per mile	.009	.016	.037	.044	.038	.050
Total miles to date	2,912	10,886	18,917	24,907	31,003	36,968

NOTE.—Cost in dollars. * Cr.

TABLE 3.

PERFORMANCE OF N. Y., N. H. AND H. R. R. ELECTRIC PASSENGER LOCOMOTIVE 037.

	1914							
	April	May	June	July	Aug.	Sept.	Oct.	Nov.
Labor	35.93	61.68	72.78	93.79	119.65	107.20	75.63	115.50
Material	4.69	35.94	159.83	102.73	212.87	184.26	209.81*	47.34
Total labor and material	40.62	97.62	232.61	196.52	332.52	291.46	134.18*	162.84
Mileage	538	4,020	5,641	7,643	8,341	7,203	7,217	6,367
Cost per mile	.075	.024	.041	.026	.040	.040	0	.026
Average cost per mile	.075	.030	.036	.032	.034	.036	.026	.026
Total miles to date	538	4,558	10.199	17,842	26,183	33,386	40,603	46,970

NOTE.—Cost in dollars. * Cr.

TABLE 4.

PERFORMANCE OF N. Y., N. H. AND H. R. R. ELECTRIC PASSENGER LOCOMOTIVE 028.

	1914					
	June	July	Aug.	Sept.	Oct.	Nov.
Labor	2.04	63.12	135.80	119.00	259.41	78.35
Material	17.25	25.15	211.95	221.73	159.11	39.25
Total labor and material	19.29	88.27	347.75	340.73	418.52	117.60
Mileage	2,103	3,902	6,788	5,398	6,526	8,256
Cost per mile	.009	.023	.051	.063	.064	.014
Average cost per mile	.009	.018	.036	.044	.049	.040
Total miles to date	2,103	6,006	12,794	18,192	24,718	32,974

NOTE.—Cost in dollars.

TABLE 5.

PERFORMANCE OF N. Y., N. H. AND H. R. R. ELECTRIC PASSENGER LOCOMOTIVE 020.

	1914					
	June	July	Aug.	Sept.	Oct.	Nov.
Labor	50.54	148.29	129.71	120.20	127.45	76.35
Material	29.84	30.19	64.29*	195.31	55.41	248.09
Total labor and material	80.38	178.48	65.42	315.51	182.86	324.44
Mileage	5,391	7,997	8,175	7,227	6,664	6,348
Cost per mile	.015	.022	.008	.043	.027	.051
Average cost per mile	.015	.019	.015	.022	.023	.027
Total miles to date	5,391	13,388	21,563	28,790	35,454	41,802

NOTE.—Cost in dollars. * Cr.

TABLE 6.

PERFORMANCE OF N. Y., N. H. AND H. R. R. ELECTRIC PASSENGER LOCOMOTIVE 016.

	(1913)	1914				
	Dec.	Jan.	Feb.	March	April	May
Labor	23.52	71.03	108.88	78.80	132.74	106.13
Material	52.16	46.61	55.88	29.91	77.26	51.72
Total labor and material	75.68	117.64	164.76	108.71	210.00	157.85
Mileage	3,260	4,820.5	5,300	5,139.5	4,868	4,222
Cost per mile	.023	.024	.031	.021	.043	.037
Average cost per mile	.023	.024	.027	.025	.029	.030
Total miles to date	3,260	8,080.5	13,380.5	18,520	23,388	27,610

	1914					
	June	July	Aug.	Sept.	Oct.	Nov.
Labor	155.66	93.52	112.85	129.38	108.75	221.59
Material	179.80	91.61	152.97	21.28	64.64	13.86*
Total labor and material	335.46	185.13	265.82	150.66	173.39	207.73
Mileage	4,347.5	8,282	8,386	5,644	8,096	5,236
Cost per mile	.077	.022	.032	.027	.021	.040
Average cost per mile	.037	.033	.033	.033	.031	.032
Total miles to date	31,957.5	40,239.5	48,625.5	54,269.5	62,365.5	67,601.5

NOTE.—Cost in dollars. * Cr.

TABLE 7.

PERFORMANCE OF N. Y., N. H. AND H. R. R. ELECTRIC PASSENGER LOCOMOTIVE 01.

	1914					
	June	July	Aug.	Sept.	Oct.	Nov.
Labor	0	96.38	156.60	175.30	133.64	81.76
Material	0	285.76	351.57	312.04	84.85	15.03*
Total labor and material	0	382.14	508.17	487.34	218.49	66.73
Mileage	571	7,183	7,396	6,006	5,812	6,842
Cost per mile	0	.053	.069	.081	.038	.010
Average cost per mile	0	.049	.059	.065	.059	.049
Total miles to date	571	7,754	15,150	21,156	26,968	33,810

NOTE.—Cost in dollars. * Cr.

TABLE 8.

PERFORMANCE OF N. Y., N. H. AND H. R. R. ELECTRIC PASSENGER LOCOMOTIVE 019.

	1914				
	July	August	Sept.	Oct.	Nov.
Labor	22.07	121.75	84.22	145.20	110.45
Material	4.18	406.70	207.84	129.73	317.68
Total labor and material	26.25	528.45	292.06	274.93	428.13
Mileage	2,886	7,894	7,766	6,938	5,056
Cost per mile	.009	.067	.039	.040	.084
Average cost per mile	.009	.051	.046	.044	.051
Total miles to date	2,886	10,780	18,546	25,484	30,540

NOTE.—Cost in dollars.

TABLE 9.

PERFORMANCE OF N. Y., N. H. AND H. R. R. ELECTRIC PASSENGER LOCOMOTIVE 05.

	1914						
	May	June	July	Aug.	Sept.	Oct.	Nov.
Labor	29.82	109.64	43.55	117.45	113.10	235.34	88.80
Material	83.60	71.29	30.86	309.76	148.05	322.91	129.96
Total labor and material	113.42	180.93	74.41	427.21	261.15	558.25	218.76
Mileage	2,268	5,432	7,937	8,566	5,497	6,783	6,578
Cost per mile	.05	.033	.009	.050	.047	.082	.033
Average cost per mile	.05	.038	.024	.032	.036	.044	.043
Total miles to date	2,268	7,705	15,637	24,203	29,700	36,483	43,061

NOTE.—Cost in dollars.

TABLE 10.

PERFORMANCE OF N. Y., N. H. AND H. R. R. ELECTRIC PASSENGER LOCOMOTIVE 011.

	1914						
	May	June	July	Aug.	Sept.	Oct.	Nov.
Labor	34.55	43.59	145.87	114.21	211.08	74.86	166.71
Material	61.61	18.69	85.08	230.08	316.83	128.33	70.75
Total labor and material	96.16	62.28	230.95	344.29	527.91	203.19	237.46
Mileage	1,017	5,671	6,243	6,837	6,078	8,122	5,690
Cost per mile	.094	.011	.037	.050	.087	.025	.042
Average cost per mile	.094	.023	.030	.037	.049	.043	.042
Total miles to date	1,017	6,688	12,931	19,768	25,846	33,968	39,658

NOTE.—Cost in dollars.

TABLE 11.

STATISTICS COVERING ELECTRIC PASSENGER MOVEMENT AND "POWER RATE" CONSTANTS FOR DIFFERENT SERVICES—EASTBOUND.

	New Haven express trains	Stamford express	Stamford local	Port Chester trains	New Rochelle trains	Total
Number of trains	52	901	667	185	2	1807
Number of locomotives	84	1407	859	214	2	2566
Number of cars	497	7,054	3,875	1,000	10	12,436
Tonnage	35,625	566,033	279,904	67,884	619	950,065
Train miles	3,120	18,921	14,003	2,405	8	38,457
Locomotive miles	5,048	30,954	18,894	2,889	8	57,793
Car miles	29,304	148,134	80,263	13,000	40	270,741
Ton miles	2,108,700	11,886,253	5,832,923	882,492	2,456	20,712,824
K. W. H. used	66,076	405,835	343,846	58,933	222	874,912
W. H. Pr. T. M.	31.4	34.2	59.0	66.7	90.2	42.2

Stamford local trains include one train, New Rochelle to Stamford.

Table 12.

STATISTICS COVERING ELECTRIC PASSENGER MOVEMENT AND "POWER RATE" CONSTANTS FOR DIFFERENT SERVICES—WESTBOUND.

	New Haven express trains	Stamford express	Stamford local	Port Chester trains	New Rochelle trains	Total
Number of trains.....	49	958	604	185	0	1,796
Number of locomotives	78	1,502	791	185	......	2,556
Number of cars.......	434	6994	3941	972	......	12,341
Tonnage............	31,963	574,569	261,202	62,559	......	930,293
Train miles..........	2,940	20,118	12,684	2405.	......	38,147
Locomotive miles......	4,620.5	33,044	17,402	2,497.5	......	57,564
Car miles............	24,855.5	146,870	81,676	12,591	......	265,992.5
Ton miles...........	1,899,957	12,065,689	5,441,943	811,539	......	20,219,128
K. W. H. used.......	60,900	486,203	346,935	62,734	......	956,772
W. H. Pr. T. M......	32.0	40.3	63.7	77·3	......	47.4

Table 13.

STATISTICS COVERING ELECTRIC FREIGHT MOVEMENT AND "POWER RATE" CONSTANTS FOR EASTBOUND AND WESTBOUND SERVICE.

	Eastbound	Westbound	Total
Number of trains............	109	116	225
Number of locomotives......	109	117	226
Number of cars	2,939	2,829	5,768
Tonnage..................	106,905	86,706	193,611
Train miles................	5,273	5,564	10,837
Locomotive miles...........	5,486	5,784	11,270
Car miles..................	142,542	135,792	278,334
Ton miles..................	5,184,893	4,161,888	9,346,781
K. W. H. used..............	170,259	137,048	307,307
W. H. Pr. T. M.............	32.8	33.0	32.9

Table 14.

COST FOR CATENARY CONSTRUCTION.

6-track compound catenary	Tangent 300′ span	Curve 0°-1′ to 1°-0′ 300′ span	Curve 1°-1′ to 2°-0′ 300′ span	Curve 2°-1′ to 3°-0′ 300′ span	Curve 3°-1′ to 4°-0 260′ span with pull-off
Steel...............	$14,390	$17,810	$19,600	$23,480	$27,500
Concrete...........	4,920	5,640	6,330	7,600	10,600
Catenary material...	16,650	16,650	16,650	16,650	17,910
Catenary labor......	2,800	2,900	2,900	2,900	3,220
Total..........	$38,760	$43,000	$45,480	$50,630	$59,230

4-track compound catenary	Tangent 300′ span	Curve 0°–1′ to 1°–15′ 300′ span	Curve 1°–16′ to 2°–15′ 300′ span	Curve 2°–16′ to 3°–1′ 260′ span	Curve 3°–1′ to 4°–45′ 260′ span with pull-off pole
Steel.	$9,350	$11,530	$13,280	$15,800	$18,850
Concrete...........	3,110	2,890	4,080	4,700	7,640
Catenary material...	11,050	11,050	11,050	11,360	12,060
Catenary labor......	1,980	2,080	2,080	2,080	2,390
Total..........	$25,490	$27,550	$30,490	$33,940	$40,940

Table 14—*Continued.*

COST FOR CATENARY CONSTRUCTION.

2-track compound catenary	Tangent 300′ span	Curve 0°–1′ to 1°–0′ 300′ span	Curve 1°–1′ to 2°–30′ 300′ span	Curve 2°–31′ to 3°–30′ 260′ span	Curve 3°–31′ to 4°–0′ 200′ span	Over 4°–1′ curve 200′ span with pull-off pole
Steel.............	$6,900	$7,220	$7,830	$9,030	$11,400	$16,160
Concrete.........	3,580	3,580	4,280	4,910	6,380	10,300
Catenary material	5,580	5,580	5,580	5,680	5,870	6,520
Catenary labor....	1,130	1,230	1,230	1,300	1,310	1,410
Total........	$17,190	$17,610	$18,920	20,920	$24,960	$34,450

2-track single catenary	Tangent and curves up to 2°–30′ 300′ span	Curve 2°–31′ to 3°–31′ 260′ span	Curve 3°–31′ to 4°–30′ 200′ span	Curves above 4°–30′ with pull-off pole 200′ span
Steel..................	$6,680	$7,700	$10,500	$14,900
Concrete................	3,000	3,300	4,600	9,000
Catenary material........	3,530	3,600	3,760	4,300
Catenary labor..........	510	510	525	650
Total..............	$13,720	$15,110	$19,385	$28,850

Table 15.

COST FOR CATENARY CONSTRUCTION.

Cost for One Mile Single Track of a 6-Track Road Compound Catenary.

Tangent 300′ span	Curve 0°–1′ to 1°–0′ 300′ span	Curve 1°–1′ to 2°–0′ 300 span	Curve 2°–1′ to 3°–0′ 300′ span	Curve 3°–1′ to 4°–0′ 260′ span with pull-off pole
$6,460.00	$7,166.60	$7,580.00	$8,438.60	$9,870.00

Cost for One Mile Single Track of a 4-Track Road Compound Catenary.

Tangent 300′ span	Curve 0°–1′ to 1°–15′ 300′ span	Curve 1°–16′ to 2°–15′ 300′ span	Curve 2°–16′ to 3°–0′ 260′ span	Curve 3°–1′ to 4°–45′ 260′ span with pull-off
$6,372.50	$6,887.50	$7,622.50	$8,485.00	$10,235.00

Cost for One Mile Single Track of a Two-Track Road Compound Catenary.

Tangent 300′ span	Curve 0°–1′ to 1°–0′ 300′ span	Curve 1°–1′ to 2°–30′ 300′ span	Curve 2°–31′ to 3°–30′ 260′ span	Curve 3°–31′ to 4°–1′ 200′ span	Curve over 4°–1′ 200′ span with pull-off pole
$8,595.00	$8,805.00	$9,460.00	$10,460.00	$12,480.00	$17,225.00

TABLE 15—*Continued.*

COST FOR CATENARY CONSTRUCTION.

Cost for One Mile Single Track of a Two-Track Road Single Catenary.

Tangent and curves up to 2°–30′ 300′ span	Curve 2°–31′ to 3°–30′ 260′ span	Curve 3°–31′ to 4°–30′ 200′ span	Curves above 4°–30′ with pull-off pole
$6,860.00	$7,555.00	$9,692.50	$14,425.00

Cost for an Anchor—and Sectionalizing—Bridge.

	Compound catenary			Single catenary 2-track
	6-track	4-track	2-track	
Steel	$3,200.00	$1,600.00	$900.00	$620.00
Concrete	2,000.00	1,270.00	960.00	700.00
Floor on upper deck of bridge	200.00	160.00	100.00	100.00
Control apparatus and connections	8,000.00	6,300.00	4,500.00	4,500.00
Sectionalizing	600.00	400.00	200.00	200.00
Total	$14,000.00	$9,730.00	$6,660.00	$6,120.00

TABLE 16.

COST FOR CATENARY CONSTRUCTION.

One mile of four-track single catenary	Tangent 300′ span	Curve up to 2°–0′ 300′ span	Curve 2°–1′ to 3°–0′ 260′ span	Curve 3°–1′ to 4°–0′ 200′ span	Curve above 4°–1′ 200′ span with pull-off
Steel	$8,800.00	$11,830.00	$13,490.00	$17,500.00	$20,500.00
Concrete	2,930.00	3,940.00	4,200.00	5,640.00	8,640.00
Catenary material	7,035.00	7,193.40	7,260.00	7,415.00	8,170.00
Catenary labor	1,237.60	1,311.50	1,320.00	1,339.00	1,540.00
Total	$20,002.60	$24,274.90	$26,270.00	$31,894.00	$38,850.00

One mile of single track of a 4-track road	Tangent 300′ span	Curve up to 2°–0′ 300′ span	Curve 2°–1′ to 3°–0′ 260′ span	Curve 3°–1′ to 4°–0′ 200′ span	Curve above 4°–1′ 200′ span with pull-off
Single catenary	$5,000.15	$6,068.74	$6,567.50	$7,973.50	$9,712.50

Anchor and sectionalizing bridge for four track single catenary.	Steel	$1,200.00
	Concrete	960.00
	Floor on upper deck of bridge	160.00
	Control apparatus and connections	6,300.00
	Sectionalizing	400.00
	Total	$9,020.00

TABLE 17.

THE NEW YORK, NEW HAVEN AND HARTFORD RAILROAD COMPANY. STATISTICS OF ELECTRICAL OPERATION—NEW YORK AND SHORE LINE DIVISIONS. FOR THE MONTH OF NOVEMBER, 1914, COMPARED WITH THE MONTH OF OCTOBER, 1914.

Cos Cob Power House.

	November		October	
	Total	Per KWH	Total	Per KWH
Coal consumed (tons)	12,439.44	2.78 lbs.	12,280.84	2.75 lbs.
Water consumed (gallons)	38,778,000	4.33 gal.	35,835,000*	4.01 gal.*
Cost of coal	$34,084.07	.381c	$33,526.69	.375c
Cost of water	1,582.15	.017	5,015.55*	.057*
Cost of other supplies	317.20	.004	655.85	.007
Maintenance of power plant and machinery	3,655.27	.041	3,434.87	.038
Wages and salaries	6,056.62	.068	6,704.00	.075
Total Cost, Maintenance and operation	45,695.31	.511	49,336.96*	.552*
Fixed charges (interest, taxes and insurance)	16,106.89	.180	16,106.89	.180
Total cost	61,802.20	.691	65,443.85*	.732*
Power Consumption (KWH)				
Passenger Service (Elec. Locos.)	2,894,465		3,072,145	
Passenger Service (M. U. Cars)	630,039		499,367	
Freight Service	1,508,306		1,494,082	
Switching Service	984,255		848,613	
Non-Revenue Service	10,340		6,191	
Total used by Electric Locomotives and Motor Cars	6,027,405		5,920,398	
Signals	107,465		117,445	
Other company purposes	389,652		399,401	
Line loss	543,235		617,804	
Total used for company purposes	7,067,757		7,055,048	
New York, Westchester & Boston	676,144		636,058	
Other companies	1,205,699		1,255,139	
Total power used	8,949,600		8,946,245	
Maximum daily output	Tuesday, November 24th 343,300 KWH		Friday, October 30th 316,630 KWH	
Maximum swing	30,000 KW Friday, Nov. 6—7.00 P.M.		29,800 KW Sunday, Oct. 4—8.27 A.M.	
Maximum daily output	Tuesday, November 3rd 249,800 KWH		Sunday, October 18th 256,155 KWH	
Average Daily Output	301,902 KWH		288,589 KWH	
Power Purchased from N. Y. C.				
Power purchased (K.W.H.)	1,244,021		1,306,017	
Cost of power	$16,097.67		$16,348.47	
Cost per K.W.H. (Cents)	1.294		1.252	
Total Power:				
Total power consumed (K.W.H.)	10,193,621		10,252,262	
Total cost of power (including fixed charges)	$77,899.87		$81,792.32*	
Cost per K.W.H. (cents) (charges)	.764		.798*	

*Revised.

Table

The New York, New Haven

Statistics of Electrical Operation
Month of November, 1914,

Passenger

	Express trains.			
	Eastbound		Westbound	
	November	October	November	October
Train miles	49,436	50,385	53,768	54,032
Locomotive miles	82,298	85,220	88,898	89,162
Car miles	386,883	404,166	410,574	425,363
Ton miles	23,880,554	24,483,292	24,654,186	25,697,939
K. W. H. used	1,120,801	1,133,588	1,231,060	1,220,947
Locomotive miles per train mile	1.66	1.69	1.65	1.65
Car miles per train mile	7.83	8.02	7.64	7.87
K. W. H. per train mile	22.67	22.50	22.90	22.60
K. W. H. per locomotive mile	13.62	13.30	13.85	13.70
K. W. H. per car mile	2.90	2.80	3.00	2.87
K. W. H. per 1000-ton mile	46.93	46.30	49.93	47.51

Operating

	Locomotive repairs		Power	
	Nov.	Oct.	Nov.	Oct.
Trains hauled by locomotives:				
Cost per train mile (cents)	17.15	13.80	19.33	19.89*
Cost per locomotive mile (cents)	10.61	8.56	11.96	12.29*
Cost per car mile (cents)	2.45	1.93	2.76	2.79*
Multiple-unit trains:				
Cost per train mile (cents)	15.27	11.83	11.39	11.42*
Cost per motor car mile (cents)	10.51	7.98	7.84	7.70*
Cost per car mile (cents)	4.32	3.12	3.22	3.01*

*Revised.

18.

AND HARTFORD RAILROAD COMPANY.

NEW YORK AND SHORE LINE DIVISIONS.
COMPARED WITH MONTH OF OCTOBER, 1914.

Service.

Local trains				Multiple-unit trains			
Eastbound		Westbound		Eastbound		Westbound	
November	October	November	October	November	October	November	October
29,128	32,941	23,839	28,622	21,569	19,338	22,552	19,363
41,148	45,008	31,558	39,722	29,937	28,504	32,220	28,857
157,770	182,564	137,502	172,338	76,544	74,004	79,292	72,793
7,314,489	8,444,023	6,432,307	7,812,994	5,093,352	4,755,814	5,296,525	4,634,919
643,284	719,423	524,871	651,374	346,385	305,267	341.496	279,137
1.41	1.37	1.32	1.39	1.39	1.47	1.43	1.49
5.42	5.54	5.77	6.02	3.55	3.83	3.52	3.76
22.09	21.84	22.02	22.76	16.06	15.79	15.14	14.42
15.63	15.98	16.63	16.40	11.57	10.71	10.60	9.67
4.08	3.94	3.82	3.78	4.53	4.12	4.31	3.83
87.95	85.20	81.60	83.37	68.01	64.19	64.48	60.22

Costs.

Locomotive Supplies		Engine house Expenses		Enginemen		Trainmen		Total	
Nov.	Oct.	Nov.	Oct.	Nov.	Oct.	Nov.	Oct.	Nov.	Oct.
2.23	1.53	.57	.54	8.81	8.37	9.51	9.55	57.60	53.68*
1.39	.95	.38	.34	5.41	5.20	5.88	5.91	35.63	33.25*
.32	.21	.08	.08	1.26	1.17	1.36	1.34	8.23	7.52*
.24	.16	.91	.78	5.17	5.20	8.84	7.53	41.82	36.92*
.17	.11	.62	.53	3.56	3.51	6.08	5.08	28.78	24.91*
.07	.04	.25	.21	1.46	1.37	2.52	1.98	11.85	9.73*

TABLE

THE NEW YORK, NEW HAVEN

STATISTICS OF ELECTRICAL OPERATION—
MONTH OF NOVEMBER, 1914,

Freight

	Fast freight.			
	Eastbound		Westbound	
	November	October	November	October
Train miles	3,283	3,484	4,954	7,576
Locomotive miles	3,283	3,486	8,042	11,128
Loaded car miles	130,147	140,202	159,377	219,435
Empty car miles	335	203	60,545	106,040
Caboose miles	3,283	3,484	4,954	7,576
Ton miles	4,399,743	4,589,492	5,941,893	8,677,627
K. W. H. used	108,749	112,033	186,401	265,088
Locomotive miles per train mile	1.00	1.00	1.62	1.47
Loaded car miles per train mile	39.64	40.24	32.17	28.96
Empty car miles per train mile	1.10	1.06	13.22	15.00
Ton miles per train mile	1,340.16	1,317,31	1,199.41	1,145.41
Ton miles per locomotive mile	1,340.16	1,316.55	738.86	779.80
Percentage of tonnage to rating	96%	95%	....	....
Ton miles per hour	26,779	27,335	19,109	18,092
Average Speed (m. p. h.)	19.98	20.75	15.93	15.79
K. W. H. per train mile	33.12	32.16	37.63	34.99
K. W. H. per locomotive mile	33.12	32.11	23.18	23.82
K. W. H. per car mile	.81	.78	.83	.80
K. W. H. per 1000-ton miles	24.72	24.41	31.37	30.54

Ton miles are based on weight of trailing load.
Percentage of tonnage to rating is found by dividing the total tonnage of trains as they leave
Ton miles per hour is found by dividing ton-miles by the total running time of trains between
Average speed is found by dividing train-miles by total running time of trains between terminals.

Operating

	Locomotive repairs		Power	
	Nov.	Oct.	Nov.	Oct.
Cost per train mile (cents)	15.51	15.98	28.51	27.90*
Cost per locomotive mile (cents)	9.69	10.19	17.82	17.79*
Cost per 1000-ton miles (cents)	9.95	10.16	18.30	17.73*

* Revised.

19.

AND HARTFORD RAILROAD COMPANY.

NEW YORK AND SHORE LINE DIVISIONS.
COMPARED WITH MONTH OF OCTOBER, 1914.

Service.

Slow Freight				Local Freight			
Eastbound		Westbound		Eastbound		Westbound	
November	October	November	October	November	October	November	October
8,485	9,177	6,152	4,880	2,880	3,240	2,933	3,240
16,529	18,038	11,269	9,824	2,956	3,321	3,012	3,321
484,644	529,559	203,556	209,889	29,965	33,893	32,990	37,339
57,346	59,801	184,978	177,831	16,304	16,339	12,072	20,456
8,485	9,177	6,152	4,880	2,880	3,240	2,933	3,240
21,121,401	22,885,161	10,496,232	10,448,521	1,301,163	1,414,569	1,432,065	1,702,877
566,983	571,972	340,830	294,602	118,423	110,757	106,650	114,828
1.95	1.97	1.83	2.01	1.03	1.03	1.03	1.03
57.12	57.71	33.09	43.01	10.40	10.46	11.25	11.52
7.76	7.52	31.07	37.44	6.66	6.04	5.12	7.31
2,489.26	2,493.75	1,706.15	2,141.09	451.79	436.60	488.26	525.58
1,277.84	1,268.72	931.43	1,063.57	440.18	426.55	475.45	512.76
94%	93%	....	....	....	....	....	....
26,008	27,912	18,637	23,297	2,614	2,679	3, 423	3,622
10.45	11.19	10.92	10.88	5.79	6.14	7.01	6.89
66.82	62.32	55.40	60.37	41.12	34.18	36.36	35.44
34.30	31.71	30.24	29.99	40.06	33.35	35.41	34.58
1.03	.96	.86	.75	2.41	2.07	2.22	1.88
26.84	24.99	32.47	28.20	91.01	78.29	74.47	67.43

Harlem River by the rating of locomotive hauling those trains.
terminals.

Costs.

Locomotive Supplies		Engine house Expenses		Enginemen		Trainmen		Total	
Nov.	Oct.	Nov.	Oct.	Nov.	Oct.	Nov.	Oct.	Nov.	Oct.
.54	.63	.48	.58	10.66	10.44	17.83	17.46	73.53	72.99*
.34	.40	.30	.37	6.67	6.66	11.14	11.13	45.96	46.54*
.35	.40	.31	.37	6.84	.663	11.45	11.09	47.20	46.38*

TABLE

THE NEW YORK, NEW HAVEN

STATISTICS OF ELECTRICAL OPERATION—
FOR THE MONTH OF NOVEMBER, 1914,

Line and Equipment

	Line											
	Catenary insulator failures				Dead end failures				Other line failures			
	Nov.		Oct.		Nov.		Oct.		Nov.		Oct.	
	No.	Total Delay	No.	Total Delay	No.	Total Delay	No.	Total Delay	No.	Total Delay	No.	Total Delay
Between Woodlawn and Stamford....	1	22	1	14	..	..	..	..	1	..	1	8
Between Stamford and New Haven...	2	..	..	..	..	..	..	..	3	41	4	47
On New Canaan Branch............	..	..	..	..	..	..	..	..	..	..	..	..
On Harlem River Branch...........	..	..	..	..	..	..	..	..	1	13	1	7
In Yards.........................	..	..	..	..	3	..	1	..	2	7	4	..
Total........................	3	22	1	14	3	..	1	..	7	61	10	62

Equipment

Class of service	Heated parts		Broken parts	
	Nov.	Oct.	Nov.	Oct.
Passenger..........................	1	4	2	1*
Freight..........................	1	2	1	2
Switch..........................	0	0	0	0
Multiple..........................	3	0	2	1*
Total..........................	5	6	5	4*

20.

AND HARTFORD RAILROAD COMPANY.

NEW YORK AND SHORE LINE DIVISIONS.

COMPARED WITH THE MONTH OF OCTOBER, 1914.

Failures.

failures

Equipment failures				Signal failures				Outside interference				Failures of employes				Total failures			
Nov.		Oct.		Nov.		Oct.		Nov.		Oct.		Nov.		Oct.		Nov.		Oct	
No.	Total Delay	No.	Total Delay	No.	Total Delay	No.	Total Delay	No.	Total Delay	No.	Total Delay	No.	Total Delay	No.	Total Delay	No.	Total Delay	No.	Total Delay
..	...	1	143	.	..	1	..	2	..	3	..	..	..	..	..	4	2	7	165
6	141	5	23	1	15	..	..	2	..	..	..	..	..	..	..	14	197	9	70
..	...	..	...	..	..	..	..	..	..	..	..	..	..	..	..	..	..	...	...
..	...	..	...	..	..	..	..	..	..	..	..	..	..	..	..	1	13	1	7
4	28	1	...	..	..	..	..	..	..	..	..	1	..	..	..	10	35		...
10	169	7	166	1	15	1	..	4	..	3	..	1	..	..	..	29	267	23	242

Failures.

Grounds		Miscellaneous		Total failures		Miles per failure		Minutes detention per failure	
Nov.	Oct.	Nov.	Oct.	Nov.	Oct.	Nov.	Oct.	Nov.	Oct.
20	25*	12	6	35	36*	7,071	7,328*	11	13*
3	2	0	1	5	7	13,183	9,506	56	60
0	0	0	0	0	0	40,964	39,624	0	0
2	0	11	11	18	12*	3,554	4,331**	18	7*
25	27*	23	18	58	55*	7,213	7,672*	17	18*

Vertical Rowland Mounting for Concave Grating. A. S. King. (*Astrophys. Journ.*, xc, 205.)—Details are given of new structural features embodied in the installation of a 15-foot concave grating on the Rowland plan, but with the plane of dispersion vertical instead of the more usual horizontal disposition. The arrangement permits placing the grating in a pit beneath the laboratory floor, thereby obtaining the constancy of temperature which has proved highly advantageous with plane grating spectrographs. The apparatus is so constructed that it may be operated in a fully-lighted room, and occupies a minimum of floor space. An ingenious arrangement is provided to allow for the variable counterpoise necessary on account of the changing angle of the beam to the vertical.

Ultraviolet Band in Ammonia Spectrum. E. P. Lewis. (*Astrophys. Journ.*, xl, 154.)—The ultraviolet band λ3295–λ3432, described by Eder as the principal band of ammonia, has been detected by the author in vacuum-tube spectra of mixtures of nitrogen and hydrogen at all pressures up to 70 cm., and becomes specially prominent when self-induction is employed. It was not found with nitrogen free from hydrogen, or hydrogen free from nitrogen. Small traces of oxygen appear to have no effect, while large quantities destroy it. Whereas the greenish-red band is found only on the first sparking, the ultraviolet band persists for long periods.

Muffling Exhaust by Turbine Wheel. Anon. (*Sci. Amer.*, cxii, No. 3, 63.)—A new form of muffler for the exhaust gases of automobile and aëroplane engines has just been brought out by a Rochester firm. It consists of a small turbine wheel which is revolved rapidly by the impinging exhaust gas, breaking its force and converting the explosive noise into a slight hissing sound. Part of the gases is caught by a baffle plate, but the back pressure caused by this is so small as to be almost negligible. There is no loss in power from the motor, and the inertia of the revolving wheel assists in drawing the exhaust gas from the pipe and manifold, even after the force of the piston movement has passed. The device takes a smaller space than the ordinary baffle plate muffler.

A Self-adjusting Piston Ring. (*Sci. Amer.*, cxii, No. 3, 63.)—Packing the pistons in an internal-combustion engine is not an easy matter, and many are the plans made to circumvent the necessity of continually adjusting and packing loose pistons. A novel type of piston ring has been invented by a Boston manufacturer, in which the use of radial holes serves to equalize the pressure between the outer and inner surfaces. The piston rings have a slightly conical shape, which causes them to be forced tightly against the cylinder walls during the compression stroke, when the tendency of "downward crowding" is at its highest.

A METHOD FOR CALCULATING THAT PART OF THE RECOIL MOMENTUM OF A GUN WHICH IS DUE TO THE ACTION OF THE GASES AFTER THE PROJECTILE LEAVES THE MUZZLE.*

BY

WM. S. FRANKLIN,

Professor of Physics, Lehigh University.
Member of the Institute.

THE object of this paper is to develop a simple point of view in the mathematical theory of wave motion, to illustrate the point of view by several simple problems, and to use the point of view in the determination of that part of the recoil momentum of a gun which is produced by the action of the gases after the projectile leaves the muzzle of the gun.

It is helpful in the study of wave motion to base everything upon a consideration of the *velocity* and *distortion* [1] of the medium at a point, because a kind of mathematical symmetry is realized thereby. To do this in the case of a transverse wave on a stretched wire or string, however, seems rather strange, because it is natural to think of a wave on a wire as a travelling bend, and this point of view directs the attention primarily to the *displacement* of the wire at each point rather than to its sidewise velocity and abnormal degree of stretch. The normal or zero condition of a stretched wire is taken as the degree of stretch of the wire as it lies in equilibrium in a straight line between its end supports as shown by the full line in Fig. 1.

The well-known expression for a pure wave travelling from left to right along a stretched string is:

$$y = f(x - ct)$$

---

* Communicated by the Author.

[1] The state of affairs at a point in a wave can be specified by giving the *velocity of the medium* and the *deformation or strain of the medium* at the point; or by giving the *velocity of the medium* and the *stress in the medium* at the point. An example of the first is to specify the state of affairs on a wire by giving its sidewise velocity and degree of stretch, and an example of the second is to specify the state of affairs in an air wave by giving the velocity of the air and the excess-pressure.

where y is the sidewise displacement of the string at the point whose abscissa is x, and c is the velocity of wave propagation. Therefore the sidewise velocity of the wire at a point is:

$$v = \frac{dy}{dt} = -cf'(x - ct)$$

and the abnormal degree of stretch of the wire at a point is:

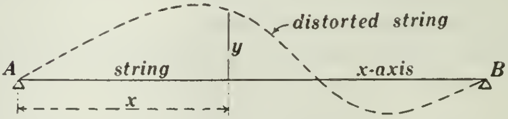
$$s = \frac{dy}{dx} = f'(x - ct).$$

Whence we get:

$$\frac{v}{s} = -c \tag{1}$$

for a pure wave travelling from left to right; and by using the well-known expression for a pure wave travelling from right to left, namely, $y = F(x + ct)$, we get in a similar manner:

FIG. 1.



$$\frac{v}{s} = +c \tag{2}$$

for a pure wave travelling from right to left.

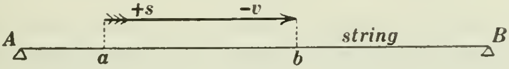
A pure wave travelling to the right is therefore a configuration of sidewise velocity and stretch in which v/s is at each point equal to $-c$, and a pure wave travelling to the left is a configuration of sidewise velocity and stretch in which v/s is at each point equal to $+c$.

A rectangular wave is one in which v (and also s) has the same value everywhere, and it is largely waves of this type which are used in the following examples. Such a wave is conveniently symbolized in Fig. 2. The arrow in Fig. 2 indicates that at every point between a and b the wire has a slope or stretch $+s$ and a downward velocity v. To represent the travel of the entire configuration to the right at wave velocity c we imagine the arrow itself to travel at velocity c.

A long-drawn-out rectangular wave which issues continuously from a point on a wire, like a ribbon issues continuously from the mouth of a prestidigitateur, is called a *ribbon wave.*

Before proceeding to the consideration of the classical problem of the plucked string, as an example, it is necessary to determine the mode of reflection of a pure wave at either end of a stretched string. Thus the rectangular wave of Fig. 2 is shown partly turned back or reflected from the end B of the string in Fig. 3. The state of stretch and the state of sidewise velocity in the original wave W' are represented by s' and v' respectively; and the state of stretch and the state of sidewise velocity in the reflected wave W'' are represented by s'' and v'' respectively. The condition which must necessarily be satisfied at B is that the actual sidewise velocity of the wire be zero there, whereas the stretch or slope can have any value whatever. Also v'/s' must be equal to $-v''/s''$ according to equations (1) and (2). Therefore we have:

FIG. 2.

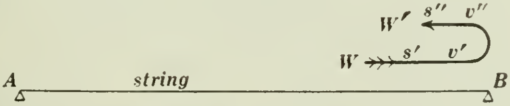


$$v' + v'' = 0 \tag{3}$$

$$\frac{v'}{s'} = -\frac{v''}{s''} \tag{4}$$

from which we find $v'' = -v'$ and $s'' = s'$. That is, the wave is reflected from the fixed end B with reversal of v but without reversal of s.

FIG. 3.



The Problem of the Plucked String.—To determine the motion of a plucked string is to discover a number of particular solutions of the differential equation of motion of the string, such that when these solutions are added together (thus giving a new solution) the initial conditions are satisfied when $t = 0$ and the boundary or end conditions are satisfied at all times. Let us therefore consider the following particular solutions of the differential equation of motion of a string as shown in Fig. 4:

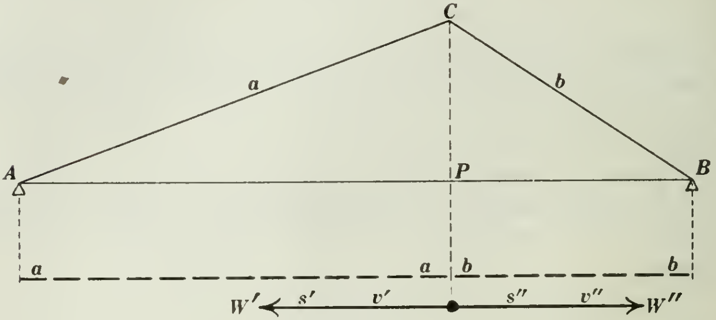
(*a*) The dotted line a which represents the initial uniform stretch of the portion AC of the string is a particular solution of the differential equation of motion of the string.[2]

(*b*) The dotted line b which represents the initial uniform stretch of the portion CB of the string is a particular solution.

(*c*) The ribbon wave W'' which is assumed to shoot out continuously to the right from the point P is a particular solution; and

(*d*) The ribbon wave W' which is assumed to shoot out continuously to the left from the point P is a particular solution.

FIG. 4.



If by choosing proper values for s', s'', v' and v'' and adding these four particular solutions together we can satisfy all of the necessary conditions, then we will have found the complete solution of our problem.

The energy stream at any point on the wire is equal to the product kvs,[3] where k is a constant for the given string, v is the total sidewise velocity of the string at the point and s is the total stretch or slope of the string at the point. Therefore the energy stream on the right of P is $kv''(b+s'')$, [illegible] the energy stream on the left of P is $kv'(a+s')$; and these energy streams are necessarily equal to each other. Therefore we have:

$$v'(a+s') = v''(b+s'') \tag{5}$$

---

[2] In fact, any equilibrium condition of a portion of the string is a particular solution for that portion.

[3] This is exactly analogous to the expression for the energy stream on an electrical transmission line, namely, EI where E is the electromotive force across the line and I is the current in the line.

Furthermore, according to equations (1) and (2), we have:

$$\frac{v'}{s'} = +c \tag{6}$$

$$\frac{v''}{s''} = -c \tag{7}$$

Also the string will break at P unless we have:

$$v' = v'' \tag{8}$$

and this is therefore a necessary equation of continuity. The initial slopes a and b and the wave velocity c are given, so that equations (5) to (8) determine v', v'', s' and s'', giving:

$$s'' = -s' = \tfrac{1}{2}(a-b) \tag{9}$$

and

$$v'' = v' = -\tfrac{1}{2}(a-b)c \tag{10}$$

The values of a and b are, of course, both expressible in terms of the initial displacement of the point P and the lengths of the segments AP and PB of the string.

It is evident that the solution shown in Fig. 4 satisfies the initial conditions, because the two ribbon waves do not exist at $t = 0$.

Also the boundary or end conditions are always satisfied by the reversal of v every time either ribbon wave is reflected at A or B.

Therefore Fig. 4 represents the correct and complete solution of the problem under consideration.

The configuration and state of motion of the string at any instant may be found by adding together the initial conditions a and b and any number of laps of the ribbon waves W' and W''. Thus Fig. 5 shows the extent of the ribbon waves after sufficient time has elapsed for each ribbon wave to travel a little more than twice the length of the string, and the actual configuration and state of motion of the string at this instant is shown at the bottom of Fig. 5. This must not be thought of as a graphical solution of the problem of a plucked string; it is an analytical solution in which any desired result having to do with the motion of the string may be calculated by arithmetical methods pure and simple.

A pipe closed at both ends contains slightly compressed air, and one end of the pipe is suddenly opened wide. It is required to determine the motion of the air in the pipe. The complete solution of this problem is shown in Fig. 6, in which the dotted line *p* represents the initial uniform compression (a particular solution of the differential equation of motion of the air in the tube), and the arrow *W* represents a ribbon wave which shoots towards the left from the open end of the tube and is repeatedly reflected at both ends of the tube (a particular solution of the differential equation of motion of the air in the tube).

Fig. 5.

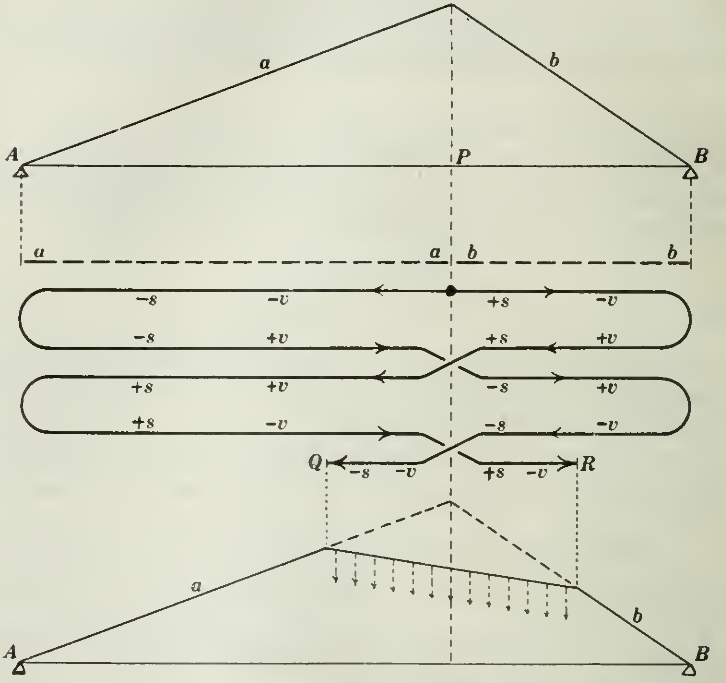
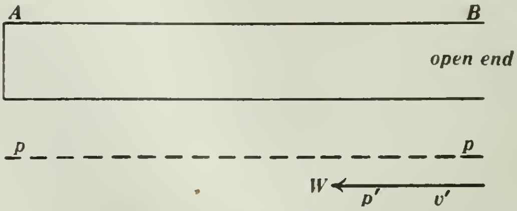


Fig. 6.



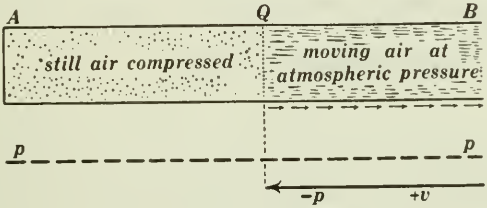
The initial conditions are evidently satisfied, because at $t = 0$ the ribbon wave does not exist.

The energy stream at B is $(p+p')v'$, and it must be equal to zero.[4] Therefore $p' = -p$.

The boundary or end conditions are always satisfied if the ribbon wave is reflected with reversal of v at the closed end of the tube and with reversal of p at the open end of the tube; that is, the pressure will always be zero (atmospheric pressure) at B and the velocity of flow will always be zero at A.

The ratio p/v in a pure wave in air is equal to $+\sqrt{\kappa\delta P}$ or to $-\sqrt{\kappa\delta P}$ according as the wave is travelling to right or to left respectively; and the velocity of wave propagation is $\sqrt{\frac{\kappa P}{\delta}}$; where κ is the ratio of the specific heats of air, δ is the density of the air, and P the absolute pressure.

FIG. 7.



The actual motion of the air in the tube is as follows: The dividing line Q, Fig. 7, between the still air and the moving air may be called a *wave sheet.* As this wave sheet travels from B to A in Fig. 7 it wipes out the excess-pressure p and lays down a uniform outward flow at velocity v. When Q reaches A the entire tube is filled with air at atmospheric pressure flowing outwards at uniform velocity v. There is then a sudden drop of pressure at A, and as the wave sheet R travels from A to B in Fig. 8 it wipes out the velocity v and leaves behind it a region of still and rarefied air.

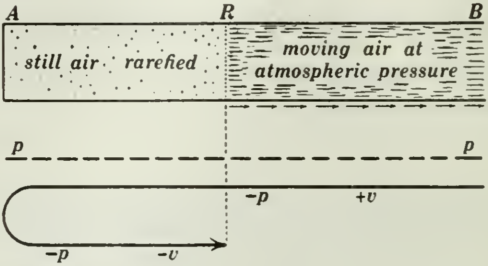
---

[4] To place the energy stream at B equal to zero is to assume that the energy stream due to convection as negligible in comparison with the energy stream due to coexistence of p and v. The energy stream due to convection is the carrying of the energy of the compressed and flowing air along with the air.

Another point of view is to consider that the air-pressure at the open end of the tube must drop instantly to zero (atmospheric pressure) and remain equal to zero, so that $p + p' = 0$. It is beyond the scope of this discussion to consider the Helmholtz end-effect, as it is also to consider that the reflection at the open end of a tube is not complete.

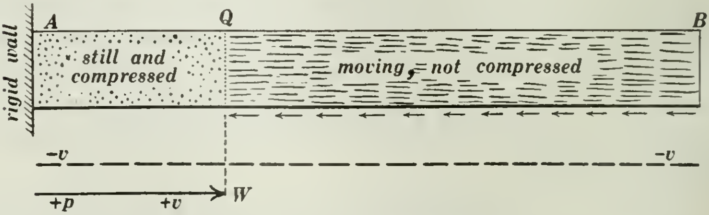
The Rebounding of a Steel Rod Which Moves Endwise and Strikes a Rigid Wall.—The complete solution of this problem is shown in Fig. 9. The dotted line $-v$ represents the initial velocity, and the arrow W represents a ribbon wave of compression p and velocity $+v$. The wave sheet Q travels at velocity $\sqrt{\frac{E}{\delta}}$, and the ratio p/v is equal to $\sqrt{\delta E}$, where E is the stretch modulus and δ is the density of the steel.

Fig. 8.



The wave sheet Q in Fig. 9 wipes out the initial uniform motion of the rod and lays down a state of compression; and the wave sheet R in Fig. 10 wipes out the state of compression and lays down a state of uniform motion to the right. When the wave sheet R reaches the end B of the rod the entire rod is free of compression and moving at velocity v away from the wall.

Fig. 9.



An Interesting Case of Wave Motion on a Cast-iron Rod.—A cylindrical slug of length L moving at velocity $2v$ strikes squarely against the end of a long rod of the same material, the diameter of the rod being the same as the diameter of the slug.

Fig. 11 shows the initial state of affairs resolved into two pure waves as represented by the two arrows W and W'. A positive value of p represents *compression* (force per unit area) and a negative value of p represents *tension*.

Fig. 12 shows the wave W' shooting outwards (to the right) and the wave W receding (travelling to the left); and Fig. 13 shows the final pure wave W' of length $2L$ which has been produced by the impact of the slug.

FIG. 10.

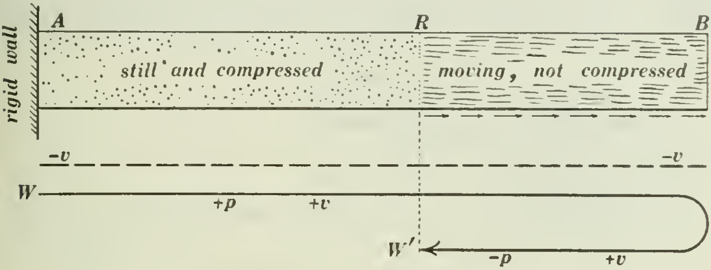


FIG. 11.

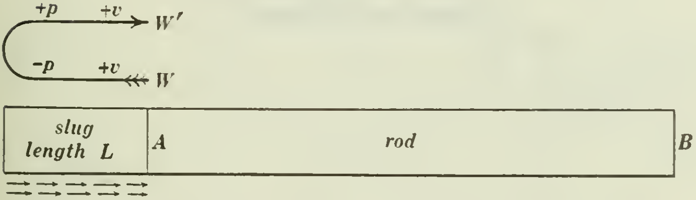


FIG. 12.

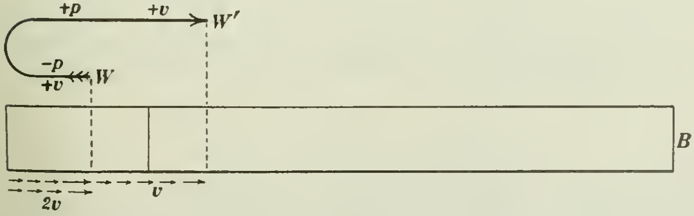


Fig. 14 shows the pure wave W' after it has left the slug high and dry, as it were. The slug has come completely to rest and is neither under compression nor under tension. The wave W' in Fig. 14 will soon reach the end B of the rod, where it will be turned back or reflected.

Fig. 15 shows the wave W' partly turned back or reflected as the pure wave W''. The compression in W' has been reversed by reflection and converted into an equal tension in the wave W'', but the velocity v has not been reversed. The portion F of the rod is therefore neither under compression nor under tension, but it is moving to the right at velocity $2v$. The portion E of the rod is moving uniformly to the right at velocity v and it is under compression p.

Fig. 16 shows the state of affairs when the wave W' is half reflected. The portion F of the rod has now the same length as the slug, it is moving uniformly to the right at velocity $2v$, and there is neither compression nor tension anywhere.

FIG. 13.

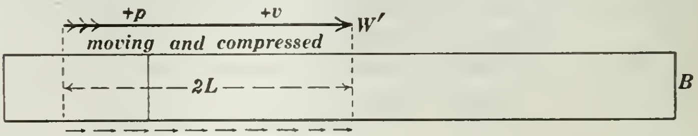


FIG. 14.

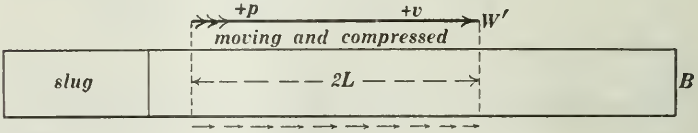
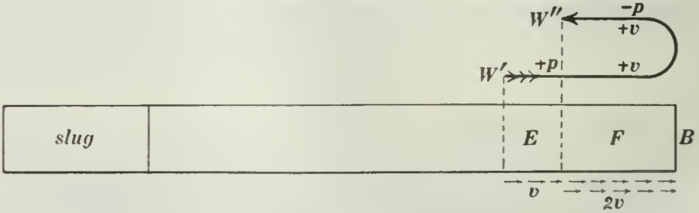


FIG. 15.



Immediately after the state of affairs which is shown in Fig. 16 the reflected wave W'' begins to show itself alone in the region G, Fig. 17, and in this region G the material of the rod is under a tension which is numerically equal to the compression in the wave W'.

The rod, being made of cast iron, can withstand a very great compression, but it cannot withstand a very great tension. Therefore, if the original velocity of the slug is sufficiently large the incipient tension in the narrow region *G* will be more than the cast iron can stand, and the portion *F*, Fig. 16, of the cast iron will fly off.

THE PROBLEM OF GUN RECOIL.[5]

The total recoil momentum of a gun may be conveniently considered in two parts; namely, (*a*) the part which is produced before the projectile leaves the muzzle, and (*b*) the part which is produced after the projectile leaves the muzzle. The part (*b*) of the recoil momentum has heretofore been calculated by entirely irrational empirical formulas, and such formulas are very unreliable when the conditions for which the calculation is to be made depart perceptibly from the conditions of the experimental tests on which the empirical formulas are based. Following is a rational method for calculating the portion (*b*) of the recoil momentum:

FIG. 16.

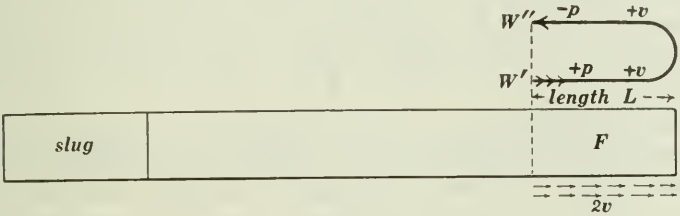
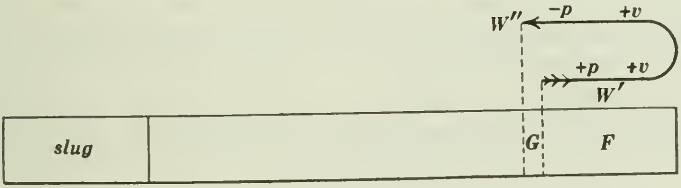


FIG. 17.



If the gases in the gun were stationary and at a uniform pressure only slightly above atmospheric pressure at the instant of opening the muzzle of the gun, then Figs. 6, 7, and 8 would give us the solution of our problem. The excess-pressure *p* would continue to exist unaltered at the breech *A* until the wave sheet *Q* of Fig. 7 had travelled from B to A, and then the pressure at A would drop suddenly to a value below atmospheric pressure. In the actual gun problem it is not necessary to consider pressure values at A below atmospheric pressure: it is only necessary to determine the march[6] of pressure values at the breech from the enormously high initial value down to atmospheric pressure P. Therefore we will ignore pressure values below P in this preliminary discussion. The force acting on the breech A in Fig. 7 is pq where q is the sectional area of the bore of the gun, and this force continues to act for L/c seconds after end B is opened, where L is the length of the gun and c is the velocity of sound. Therefore pqL/c is the impulse value of the backward force on the breech, and this impulse value is equal to the momentum produced.

---

[5] Throughout this paper f.p.s. units are used; length in feet, mass in pounds, time in seconds, force in poundals, energy in foot-poundals, pressure in poundals per square foot, density in pounds per cubic foot, etc.

The above calculation is not applicable to the gun problem, however, for three chief reasons; namely, (a) the gases have a certain velocity of flow at the instant the projectile leaves the muzzle; (b) the gases do not have a uniform pressure at the instant that the projectile leaves the muzzle; and (c) the range of expansion of the gases in a gun after the projectile leaves the muzzle is so great that there is no definite wave velocity and the velocities of flow reach thousands of feet per second. In making allowance for these three things we will retain the simple theory of wave motion in discussing (a) and (b), and we will then discuss (c) and secondary influences of (a) and (b) on the basis of a modified wave theory.

Discussion of Initial Velocity of Flow of Gases.—A gun tube is filled with gas which is everywhere at atmospheric pressure, but the gas is moving at small velocity v, towards the muzzle, the value of v being proportional to $(L-x)$, so that we may write:

$$v = a\,(L - x) \qquad (11)$$

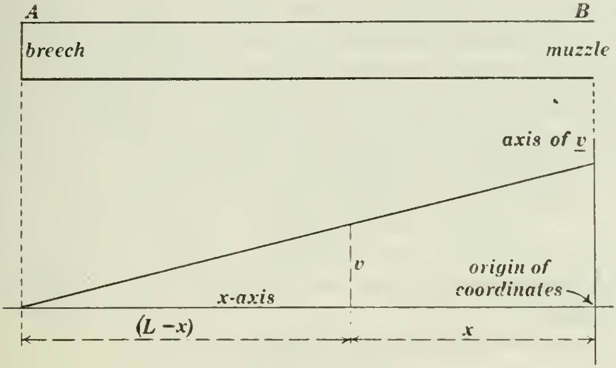
where a is a known constant. The specified velocity distribution is represented in Fig. 18, and (with normal atmospheric pressure everywhere) it constitutes what is called an *impure wave*,[7] which is resolvable into two pure wave components, one of which travels towards the muzzle and involves half of the specified velocity of flow and a *pressure rise* equal to $\frac{1}{2}a(L-x)\sqrt{\kappa\delta P}$; and the other of which travels towards the breech and involves the other half of the specified velocity of flow and a *pressure drop* equal to $\frac{1}{2}a(L-x)\sqrt{\kappa\delta P}$. These two pure waves are represented in Figs. 19 and 20.

---

[6] To determine the *march* of a varying quantity is to determine it as a function of elapsed time.

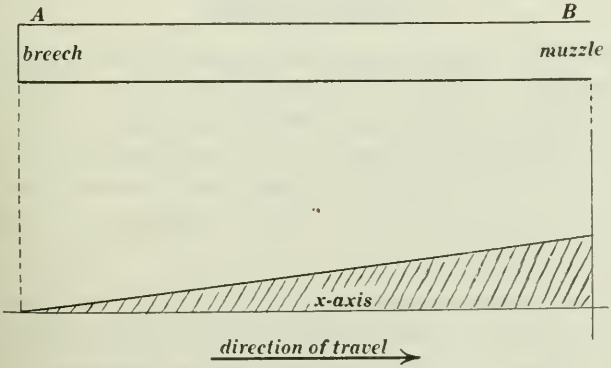
[7] See Franklin and MacNutt's "Advanced Electricity and Magnetism," p. 222. The Macmillan Company, 1915.

FIG. 18.



The wave in Fig. 19 is travelling away from the breech, and, although it is partially reflected at the open end *B* of the tube, it finally reaches the breech too late to modify the march of pressure values at *A* in which we are interested. The wave in Fig. 20 is reflected at the breech with reversal of *v* but without reversal of pressure drop. Therefore, inasmuch as the actual drop of pres-

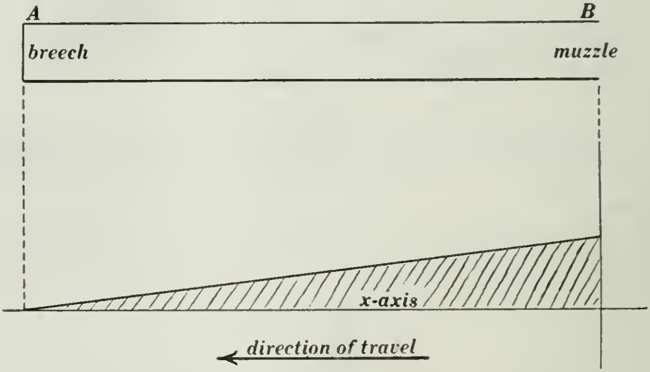
FIG. 19.



sure at the breech is the sum of the pressure drops in the original and reflected waves, it is evident that this wave causes a uniform drop of pressure at the breech which amounts to $aL\sqrt{\kappa\delta P}$ during the time required for sound to travel from B to A.

Discussion of Combined Effect of Initial Variation of Pressure and Initial Velocity of Flow.—A gun tube is filled with gas which is everywhere moving in accordance with equation (11), and the slight excess-pressure (above atmosphere) is p at the breech and $p-b(L-x)$ at a point x feet from the muzzle. In this case the uniform pressure-excess p is wiped out by a wave sheet, as explained in connection with Figs. 6, 7, and 8; the velocity distribution is resolved into two wedge waves, as indicated in Figs. 19 and 20 and as explained above; and the pressure deficiency $-b(L-x)$ constitutes an impure wave which is resolvable into two pure wave components, one of which travels towards the muzzle and need not be considered, and the other of which travels towards the breech and involves half of the pressure deficiency $\frac{1}{2}b(L-x)$ and corresponding *outward flow* $\frac{1}{2}b(L-x) \div \sqrt{\kappa\delta P}$.

FIG. 20.

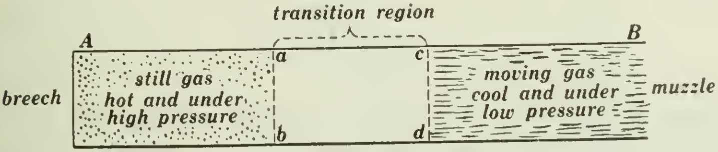


The two wedge waves which travel towards the breech merge into a single pure wedge wave in which the pressure drop is $\frac{1}{2}b(L-x)+\frac{1}{2}a(L-x)\sqrt{\kappa\delta P}$, and this wedge wave is reflected at the breech with reversal of v but without reversal of pressure drop. Therefore, inasmuch as the actual drop of pressure at the breech is the sum of the pressure drops in the original and reflected waves, it is evident that this wedge wave causes a uniform drop of pressure at the breech which amounts to $bL + aL\sqrt{\kappa\delta P}$ during the time required for sound to travel from B to A; and then the wave sheet Q, as above explained, causes the pressure at the breech to drop suddenly to a value below atmospheric pressure.

According to this analysis the calculation of the impulse value of the backward force on the breech would be as follows: The force on the breech drops at a uniform rate from pq to $(p - bL - aL\sqrt{\kappa\delta P})q$ during L/c seconds and then drops suddenly to a value below P. Therefore the average value of the force during the L/c seconds is $(p - \frac{1}{2}bL - \frac{1}{2}aL\sqrt{\kappa\delta P})q$, and its impulse value is found by multiplying this average value by L/c.

Inadequacy of Simple Wave Theory.—The above simple calculations are very considerably in error, because there is no definite wave velocity (velocity of sound) for so wide a range of expansion as that which takes place in the gases in a gun after the projectile leaves the muzzle. Indeed, the wave sheet Q in Fig. 7 is actually a long-drawn-out transition region between the hot and compressed gases and the expanded and cooled gases, as shown in Fig. 21. The boundary ab in Fig. 21 has a definite velocity (the "velocity of sound" in the hot and high pressure gases), and the boundary cd, if it exists, has a definite velocity, namely, $(c - v)$ where c represents the "velocity of sound" in the expanded and cooled gases and v represents the velocity of flow of the expanded and cooled gases. Usually, however, v (as here defined) is greater than c (as here defined), so that the boundary cd is carried out beyond the muzzle and lost.[8] Therefore when the boundary ab (the point r in Fig. 22) reaches the breech the transition region fills the entire gun tube.

FIG. 21.



---

[8] The carrying of the boundary cd out beyond the muzzle means that gas far above atmospheric pressure flows out of the muzzle, and it is the sidewise expansion of this gas which produces the mushroom cloud of smoke at the muzzle.

Gas at a very high pressure p_0 fills a tube *AB*, Fig. 22, which is permanently closed at the end *A*. The other end *B* is closed by a piston which is released at $t = 0$. This piston is supposed to be without mass and its motion is supposed to be hindered by a force which is exactly equivalent to atmospheric pressure *P* exerted over its outside face. It is desired to determine the motion of the gas in the tube *AB*, friction being ignored. The initial distribution of pressure is represented by the curve p_0p_0g in Fig. 22.

For each infinitesimal step of pressure drop an action essentially like that shown in Fig. 7 takes place. Consider, for example, the pressure drop from $p + \Delta p$ to p, where p is any pressure between p_0 and P. The wave sheet (like *Q* in Fig. 7) which carries this pressure drop along travels, *with respect to the gas*, at the velocity of sound which corresponds to the state of the gas at pressure p; that is, at a velocity c which is given by:

$$c = \left(\frac{\kappa p_0^{\frac{1}{\kappa}}}{\delta_0}\right)^{\frac{1}{2}} p^{\frac{\kappa-1}{2\kappa}} \tag{12}$$

where κ is the ratio of the specific heats of the gas, and δ_0 is the initial density of the gas at pressure p_0. The velocity of flow v of the gas which has expanded adiabatically from p_0 down to p is given by placing the kinetic energy per pound equal to the work done by adiabatic expansion per pound, whence:

$$\tfrac{1}{2}v^2 = \frac{p_0^{\frac{1}{\kappa}}}{\kappa\delta_0}\int_{p=p_0}^{p=p} p^{-\frac{1}{\kappa}} \cdot dp$$

which gives:

$$v^2 = \frac{2p_0}{(\kappa - 1)\delta_0}\left[1 - (p_0p)^{\frac{\kappa-1}{\kappa}}\right] \tag{13}$$

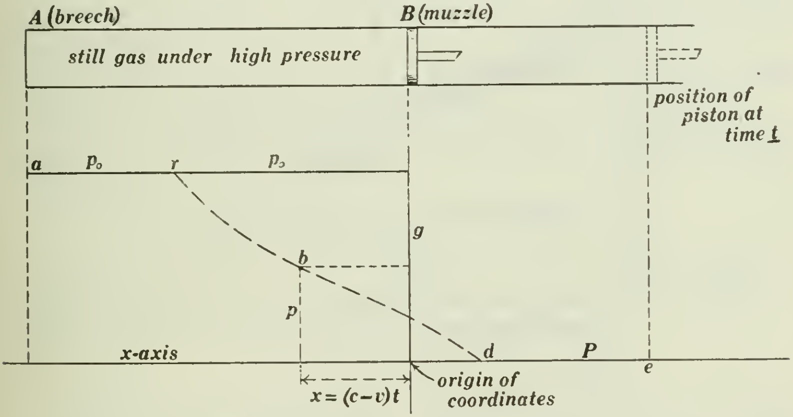
where v is the velocity of flow of the gases at the point x in Fig. 22. Substituting the values of c and v from equations (12) and (13) in the expression for x which is given in Fig. 22, namely, $x = (c - v)t$, we get an equation between x and p which is the equation to the dotted curve in Fig. 22, and the complete curve *arbde* in Fig. 22 is the curve of pressure distribution at the instant t.

Outline of Approximate Solution of the Gun Recoil Problem.

—The principle of superposition is not valid for the wave motion which takes place in the gases in a gun after the projectile leaves the muzzle; nevertheless, we use this principle in the following, and some of the correction terms make partial allowance for the invalidity of the principle.

Data.—At the instant $t = 0$, when the projectile leaves the muzzle of the gun, the pressure of the gas at the breech is p_0, the density of the gas is δ_0, and the ratio of the specific heats of the gas is κ. The pressure tapers off from p_0 at the breech to $(p_0 - bL)$ at the muzzle, and the velocity of flow of the gases as given by the equation $v = a(L - x)$; a and b being given. In the following discussion p_0 and p refer to absolute pressures. The length of the gun tube is L and the sectional area of bore is q. The origin of coördinates is at the muzzle, the x-axis is the axis of the gun tube, and the abscissa x is measured from the muzzle towards the breech, as shown in Figs. 22 and 23.

FIG. 22.



Step 1.—Calculate the time t_1 required for the point r in Fig. 22 to travel from muzzle to breech, assuming average outward velocity of flow of gases during the whole time to be $\frac{1}{2}aL$, and assuming average wave velocity with respect to gases to be that which corresponds to a pressure equal to $p_0 - \frac{1}{2}bL$. That is, use this value for p in equation (12), calculate c, and then the average velocity of r with respect to the gun will be $c - \frac{1}{2}aL$, and the desired value of $t_1 = L/(c - \frac{1}{2}aL)$.

Remark.—During the time t_1 the pressure at the breech drops from p_0 to $p_1 = p_0 - bL - aL\sqrt{\kappa\delta_0 p_0}$, as shown in Fig. 24.

Step 2.—Calculate from equation (13) the velocity of flow v corresponding to adiabatic expansion from p_0 to $p = \frac{1}{2}(P + p_0)$; calculate the value of c corresponding to this value of p, using equation (12); and calculate the value of x in Fig. 23 corresponding to the instant when the point r in Fig. 22 has reached the breech; that is, after time t_1 has elapsed. The desired value of x is $(c - v)t_1$[9] *lessened* by the amount $v'\ t_1$, where v' is the average value of the initial velocity of flow between $x = 0$ and $x\ (c - v)t_1$.

FIG. 23.

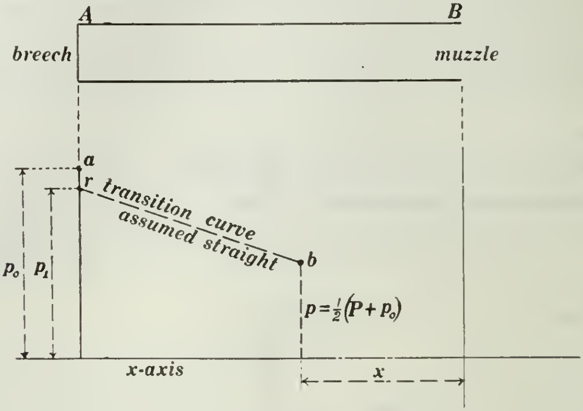
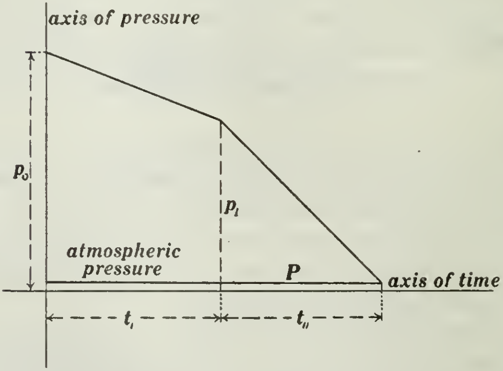


FIG. 24.



---

[9] The values of c and v are those referred to in the same sentence.

Remark.—The state of affairs at $t = t_1$ is shown in Fig. 23, and we will now assume that the portion rb of the transition region [the point r having reached the breech, and the point b corresponds to $p = \frac{1}{2}(P + p_o)$,] travels to the left as a simple wave at velocity $c'' - v''$ with respect to the gun tube, and is reflected at the breech with reversal of velocity of flow but without reversal of pressure drop, where c'' is the velocity of sound as given by equation (12) for a pressure midway between p_o and p, and v'' is one-half the velocity of flow as given by equation (13) for adiabatic expansion from p_o to $p = \frac{1}{2}(P + p_o)$.

Step 3.—Calculate the time $t_{11} = \frac{L-x}{c''-v''}$ where x has the value as calculated in Step 2, and c'' and v'' are as explained in the above remark.

Remark.—During the time t_{11} the pressure at the breech falls from p_1 to P, as shown in Fig. 24.

Step 4.—Calculate the impulse value of the backward force on the breech. It is equal to

$$\left[\tfrac{1}{2}(p_o + p_1)t_1 + \tfrac{1}{2}(p_1 + P)t_{11} - P(t_1 + t_{11})\right]q,$$

as may be understood from Fig. 24. This impulse value is equal to that part of the recoil momentum of the gun which is produced after the projectile leaves the muzzle.

Collodion Enamels for Leather. T. CALLAN. (*Leather World*, vi, 523.)—Collodion enamels for leather usually contain nitrocellulose; solvents, boiling-point 55° to 80° C., such as acetone, ethyl acetate, and camphor dissolved in alcohol; solvents, boiling-point 110° to 160° C., such as amyl acetate and amyl formate; diluting agents such as petroleum hydrocarbons, benzene, and methylated spirit; softening agents such as castor or linseed oils; coloring matters. Enamels prepared with low-boiling solvents only will not give a coherent film on evaporation except in a warm, dry atmosphere, as the rapid evaporation of the solvent cools the enamel, moisture is condensed from the air, and the nitrocellulose is precipitated as a white powder. The addition of a high boiling solvent reduces the rate of evaporation, thus preventing surface cooling, and gives a brilliant film. With a nitrocellulose soluble in a mixture of camphor, alcohol, and benzene of ninety per cent., these solvents can be used as cheap diluting agents. The addition of castor oil or linseed oil makes the enamel more flexible, but also softer and less durable, hence most of the oil should be in the lower coats. The coloring matters are usually pigments, but occasionally spirit-soluble dyes are employed.

Oil for Electrical Purposes. C. C. GARRARD. (*Electrician,* lxxiii, 797.)—This article gives a short account of tests which should be applied to oils used for insulation purposes in oil switches and in oil-cooled transformers. The oils generally employed at the present time are hydrocarbons, principally of the paraffin series, obtained by the distillation of the crude petroleum. Three simple tests are given to indicate the presence of moisture, which must be particularly guarded against; if necessary it may be removed by passing the oil through dried filter paper in a filter press. A more reliable method of testing for moisture is to determine the dielectric strength by finding the breakdown voltage between two spheres immersed in the oil. A simple point and plane dielectric test is also described. The value obtained should not be less than about 90,000 volts per centimetre. Tests should be applied to show the absence of acid or alkali and sulphur. The oil should not flash at less than 190° C. as determined on the Gray flash-point apparatus, when intended for use in switches, but for transformers it may be some 35 degrees lower. The viscosity of the oil is a matter of small importance in transformers, but for switch-work certain limits should be specified. A satisfactory oil would have a viscosity as determined on the Redwood viscosimeter of not more than 850 secs. at 4° C. and not less than 100 secs. at 21 ° C. Oils, particularly those for transformer use, should not show any appreciable tendency to "sludge," due to oxidation of some of the constituents of the oil.

Combustion of Coal in Boiler Furnaces. J. K. CLEMENT, J. C. W. FRAZER, and C. E. AUGUSTINE. (*U. S. Bureau of Mines,* Paper 63.)—Experiments with a furnace having an unusually long combustion chamber, from which samples of the gases could be drawn at intervals along its length, showed that with a constant rate of firing the time necessary for complete combustion of the gases, and hence the length of chamber required, decreases with an increasing air supply.

Bearing Metals. ANON. (*Amer. Mach.*, xli, No. 18, 760.)—Bearing metals or linings may be classified under two heads—babbitt metals, which are largely tin, lead, antimony, and some copper compositions, and brasses and bronzes, which are tin, copper, and zinc compositions, sometimes containing certain percentages of lead. Babbitts range in composition from a cheap metal containing 90 pounds lead and 10 pounds antimony to mixtures containing about 88 pounds tin, 4 pounds copper, and 8 pounds antimony. Babbitt metals are divided into three classes: the lead-based anti-friction metals, in which the lead content is the heaviest, the smaller percentages being tin and antimony; the semi-tin-based metals, in which the tin and lead contents are about equal, leaving room for ten to twenty per cent. antimony; and the tin-based metals, which range from 75 pounds to 90 pounds tin in each 100 pounds.

GLASSES FOR PROTECTING THE EYES FROM INFRA-RED RAYS.*

BY

W. W. COBLENTZ, Ph.D.,
Associate Physicist, U. S. Bureau of Standards.

ALTHOUGH it does not appear to be definitely settled that the infra-red rays from incandescent sources, such as molten metal, etc., are injurious to the eye, there is nevertheless considerable agitation to protect the eyes of workmen who are subjected to the intense heat coming from molten metal, and especially (for glass blowers) from furnaces containing molten glass.

Some years ago I examined [1] a series of colored glasses, but found none which had a marked absorption in the infra-red—other than the usual opacity, beyond 3.5 μ, which obtains in ordinary, visually transparent glass. Fortunately glass manufacturers are taking an active interest in this matter, and, by employing trained investigators, seem to be at the point of producing glasses which are almost entirely opaque to infra-red radiations. Their tests, which may show that a glass absorbs, say, ninety per cent. of the infra-red, do not elucidate matters very much; for much depends upon the distribution of energy in the spectrum of the source. During the past two years frequent inquiries have been made concerning the reliability of such claims, and recently, at the request of Mr. I. G. Priest, who submitted several samples of glass made by the Corning Glass Works, I made a further examination into this matter. Believing that the data obtained will be useful to the public, they are herewith presented.

Referring to Fig. 1, curve No. 1 gives the transmission through a sample of glass, 1.47 mm. in thickness, which had a yellowish-brown color, and having the maker's number, "G124, H.L., shade No. 1." Curve No. 2 gives the transmission through a much more opaque sample of the same kind of material, 2.16 mm. in thickness, and marked "G5, C.A.D., shade No. 4." It transmits about 5 per cent. in the "orange" part of the spectrum, while the former transmits almost 30 per cent. in the "orange."

These samples absorb also the violet end of the spectrum.

The most interesting sample examined had a faintly bluish tint, being quite colorless. Nevertheless the infra-red is marked by almost complete opacity. The transmission curve is given as No. 3 in the accompanying illustration, the thickness being 2.6 mm., and the maker's number being "G124 J." This will make excellent spectacle glass for working near a "red-hot" source which emits but little light, but which emits a great deal of "heat," —*i.e.*, infra-red radiations.

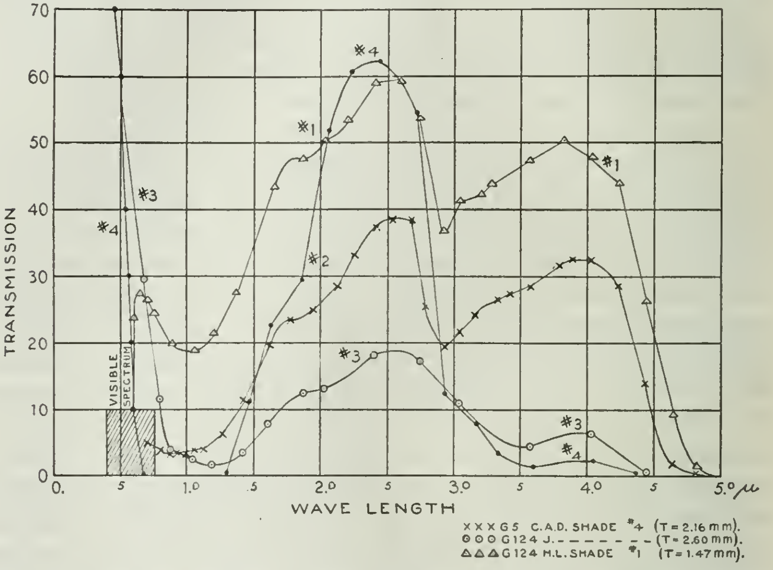
---

* Communicated by the Author.

[1] Publication No. 97, Carnegie Institution of Washington, 1908.

Referring to the previous publication,[1] it was shown that

Fig. 1.



ordinary black glass ("smoked glass") is quite transparent in the infra-red, although it is quite useful for reducing the visible radiations. Indeed, the present sample of blue glass is the first one which the writer has found to fulfil the claim of great opacity in the infra-red. Another blue glass (Corning G401 ZA and Schott's blue-violet glass No. F3086) has practically the same form of transmission as Curve No. 3 in the infra-red. The transmission curve is given in Fig. 1, No. 4. The peculiarity of this glass is that a high transmission in the visible gives a high transmission at 2.2 μ.

It appears as though in the near future glasses fulfilling every requirement will be obtainable, and it speaks well for American enterprise to be willing to spend a few dollars in attempting to produce devices for safeguarding the health and contentment of the public.

THE BEHAVIOR OF ENZYMES AT LOW TEMPERATURES.*

BY

JOSEPH SAMUEL HEPBURN, A.M., M.S., Ph.D.,

University Fellow in Biological Chemistry, Columbia University, 1912–1913.
Member of the Institute.

The influence of low temperatures on enzymes is a subject of growing importance to the chemist, the biologist, and the bromatologist. Problems in this field may be studied from either the potential or the kinetic side; for either the resistance of an enzyme to, or its activity at, low temperatures may be investigated. Various researches, conducted during the last half century, have demonstrated that enzymes survive exposure to low temperatures and also act as catalysts at such temperatures. The reports of these researches are widely scattered in the literature; and frequently the original papers may be obtained for consultation only with difficulty. It is the purpose of this paper, which is based on primary sources, to give a *résumé* of our present knowledge of this subject. One section is devoted to the resistance of enzymes to low temperatures, and one to their activity at such temperatures.

THE RESISTANCE OF ENZYMES TO LOW TEMPERATURES.

The researches reviewed below demonstrate that the following enzymes survive exposure to low temperatures and again exert their usual catalytic power when brought into a suitable environment: diastase, inulinase, invertase, maltase, zymase, lipase, protease of plants, pepsin, trypsin, thrombin, rennin, oxidase, peroxidase, catalase, simple and aldehyde reductase. This order will be followed in presenting the data.

Solutions of *diastase, inulinase,* and *invertase,* after exposure for forty-five minutes to the temperature of liquid air (approximately — 191° C.), retained unaltered their power to hydrolyze starch, inulin, and sucrose respectively. The diastase was obtained from human saliva and from *Aspergillus niger;* the inulinase from that Aspergillus; and the invertase from both that Aspergillus and beer yeast.

---

* Communicated by the Author. This contribution is based on a paper to be published by the writer in the *Biochemical Bulletin,* 1915, iv.

In this paper full details will be given of the researches of various investigators on the influence of low temperatures on enzymes, and a complete bibliography appended.

After yeast press juice had been repeatedly cooled to — 2° C., its *maltase* retained the power to invert maltose.

Zymase in yeast press juice survives complete freezing of the juice. The enzyme may be concentrated by cooling the juice to — 2° C. and removing the ice crystals from the solution of enzyme in the mother liquor. Zymase has been prepared by trituration of a mixture of solid carbon dioxide (carbon dioxide snow)[1] and dehydrated yeast cells for a period of one-half hour. It is resistant to a temperature of — 182° to — 190° C., that of liquid air; for yeast cell plasma, held at that temperature for twenty hours, retained unchanged its power to produce alcoholic fermentation.

The *lipase* of a pig pancreas, which had been kept in cold storage at 4° C. for seven days, retained about forty per cent. of its power to hydrolyze ethyl butyrate. Lipase was found in fresh eggs which had been held at 0° C. for sixty-six days. It was present in the crude abdominal fat of a chicken kept at 0° C. for twenty-four hours after death, in that of chickens of known history held hard frozen for periods of twelve and one-half, thirteen, sixteen, twenty-eight, twenty-nine, and forty-two months at a temperature of — 9.4° to — 12.2° C., and in that of birds, whose history prior to freezing was unknown, kept at that temperature for periods of fifty-four and eighty-nine months.

The *protease of plants* survives freezing temperatures. Sprouting wheat seedlings, excoriated peas, excoriated germinating peas, etiolated caulis tops, etiolated leaves and green leaves of the bean *Vicia faba* were frozen, usually for twenty-four hours. Their proteases were still able to produce autolysis of the tissue proteins at room temperature.

Solutions of *pepsin* and *trypsin,* after exposure to the temperature of liquid air (approximately — 191° C.) for forty-five minutes, were practically unaltered in their ability to digest albumin.

---

[1] The temperature of solid carbon dioxide vaporizing at ordinary atmospheric pressure is approximately −75° C. (Richter *Inorganic Chemistry,* Fifth American Edition, p. 228.)

The clotting enzymes *thrombin* and *rennin* likewise survive exposure to the temperature of liquid air. Thrombin of dog's blood held at — 180° C. for thirteen minutes retained in full its power to produce clotting of the blood.

Commercial rennet, kept at — 180° C. for periods of one, five, ten, and thirty minutes, was entirely unchanged in its action on milk at 35° C. In another experiment a rennin solution, which was kept in boiling liquid air for over one hour, retained completely its power to produce clotting of milk.

Oxidase was present in milk held at 0° C. for as long as thirty-five days, and in cream held at that temperature for as long as twenty-eight days. Both milk and cream were rendered bacteriologically sterile by addition of 0.1 per cent. of formaldehyde before storage.

Both oxidase and *peroxidase* were found in the crude fat of a chicken kept at 0° C. for fifteen days after death, and in that of hard-frozen chickens, including birds of known history, kept in the freezer for nine months and birds, whose history prior to freezing was unknown, held in the freezer for periods of twenty-three and sixty-three months; the temperature of holding was — 9.4 to 12.2° C.

Catalase has been found in milk and cream rendered sterile by addition of 0.1 per cent. of formaldehyde and held at 0° C. for twenty-one days. It has also been detected in eggs, including both the white and the yolk, after the eggs had been kept at 0° C. for sixty-five days.

Catalase has also been demonstrated in the crude fat of chickens of known history held hard-frozen for nine months at a temperature of — 9.4 to — 12.2° C., in sole kept frozen for nineteen to twenty-one days at — 2° to — 9.5° C., and in cod kept frozen for thirty days at — 2° to — 6.5° C.

Simple reductase has been found in formolized, sterile milk and cream kept at 0° C. for twenty-eight days; the cream also contained *aldehyde reductase.*

Simple reductase occurred in the crude fat of chickens of known history held hard-frozen for nine months, and in that of chickens, whose history prior to freezing was unknown, kept in the freezer for twenty-three months. Aldehyde reductase was present in the birds of the latter class after periods of twenty-three and sixty-three months in the freezer. The temperature of holding was — 9.4° to — 12.2° C.

THE ACTIVITY OF ENZYMES AT LOW TEMPERATURES.

Studies have been made of the activity of the following enzymes at low temperatures: invertase, maltase, zymase, diastase, lipase, pepsin, trypsin, galactase, urease, rennin. This order will be followed in presenting the data. At times the enzyme studied was permitted to produce an autolysis, at times to act in solution on an artificial medium, at a given low temperature.

Invertase, maltase, and *zymase* are active at the temperature of an ice-box, for yeast press juice ferments saccharose, maltose, glucose, and fructose at that temperature.

The *diastase* of carp liver acts on starch at 0° C., converting it first into soluble starch, then into erythrodextrin, and finally destroying the latter compound.

The *lipase* of pig pancreas has been shown to hydrolyze ethyl butyrate at 0° C., and to hydrolyze neutral lard at — 9° to — 12° C. The lipase of pig liver splits ethyl butyrate at 0° C. and at — 10° C. The lipase of crude chicken fat produces hydrolysis of ethyl acetate, butyrate, and benzoate and amyl salicylate at 0° C. and at a temperature of — 6.7° to — 9.4° C.

Pepsin.—The gastric protease of the frog, the pike, and the trout digests albumin at 0° C.; that of the frog also digests fibrin at 0° C., while that of the pike produces proteolysis of fibrin at temperatures as low as 0° C. Pepsin of pig's stomach converts coagulated ovalbumin into acid albumin, albumoses, and peptones at 0° C. Pepsin also digests ricin at that temperature.

Trypsin, derived from the intestinal tract of the carp, gave rise to proteolysis of gelatin and of fibrin at 0° C.

Galactase, the trypsin-like enzyme of milk, gives rise to a proteolysis in Cheddar cheese which is ripened at 15° F. (— 9° C.), 25° to 30° F. (— 1° to — 4° C.), and 33° F. (+ 0.6° C.). Galactase also produces proteolysis in milk rendered sterile by addition of 0.1 per cent. of formaldehyde and held at 0° C. The digestion of the proteins observed in milk kept at — 9° C. has been ascribed to the action of galactase.

Urease of the soy bean hydrolyzed urea at temperatures as low as 0° C.

When *rennin* acts on milk it first transforms the casein into paracasein and then precipitates the latter compound as a coagulum. The first stage of the reaction occurs at 0° C.; the second stage likewise takes place at that temperature, but the precipitate separates in a finely-divided condition without the formation of a distinct curd.

SUMMARY.

The power to survive prolonged exposure to low temperatures is possessed by various enzymes, including those producing hydrolysis of fats, of carbohydrates, and of proteins, those concerned in biochemical oxidations and reductions, the clotting enzymes and that of alcoholic fermentation. The enzymes retained their catalytic power after exposure, either *in situ* or in solution *in vitro,* to temperatures varying from a few degrees above 0° C. to the temperature of liquid air (—180° to —191° C.). The shortest periods of holding, invariably less than one day and usually less than one hour, were at the temperature of liquid air. The longest period of holding was eighty-nine months at a temperature of — 9.4° to — 12.2° C.

The activity of certain of these enzymes, including rennin, zymase, and those hydrolyzing fats, carbohydrates, and proteins, has been studied at low temperatures, varying from that of an ice-box to one of — 9° to — 12° C. While the enzymes produced autolytic digestion or acted on artificial media at these temperatures, the velocity of the reaction was always lessened to a considerable degree.

Electric Tanning. O. J. WILLIAMS. (*Collegium,* dxv, 76–78.)—Electric tanning not having been successful, the author investigates in this preliminary note whether the electric current destroys the tannic acid as observed by Nierenstein. Electrolyzing pure tannic acid (five per cent. aqueous solution) 15° C. between carbon plates with continuous currents of 0.004 amp./cm.^{2} he finds that the optical activity (Nierenstein's method) of the solution is rapidly diminished. In other experiments in which platinum electrodes and currents of up to 0.075 amp./cm.^{2} continuous or 93 periods per second were used, the alternating currents did not destroy the tannin whilst favoring the electric endosmose, in accordance with F. Rolver. The electromotive force applied is not stated.

Electrolytic Iron. L. GUILLET. (*Iron and Steel Institute J.*, xc, 66.)—Since 1910 the Company Le Fer, of Grenoble, has manufactured electrolytic iron by using a revolving kathode in an electrolyte of neutral iron salts. The bath is circulated, and oxide is added periodically to act as a depolarizer. Using pig iron containing 2.35 C, 1.31 Si, 0.07 S, and 1.07 per cent. P, it is possible to obtain a product having the following analysis after annealing: C, 0.004; Si, 0.007; S, 0.006, and P, 0.008 per cent. The crude material is hard and brittle, showing a ball hardness of 193. Annealing commences at about 300°, but it is not complete until heated at 900° C. for some time; the material then has a hardness of 90. Determination of the values of the physical properties of the annealed metal gives results which agree closely with those previously published. With regard to the industrial applications of the material, it can readily be deposited in the form of tubes and sheets. On account of their high degree of purity the sheets are specially adaptable to the construction of electrical machinery. Their favorable values as regards hysteresis and permeability render it possible to effect considerable economies in the weight of transformers and direct-current machines, and to increase the capacity of alternating-current motors. As a raw material for fusion electrolytic iron will undoubtedly be able to enter into direct competition with Swedish iron, over which it possesses the advantages of being more uniform in quality and more readily broken into pieces of any desired size. The cost of production varies from £5 to £7 12s. per ton, according to the local conditions.

Zinc as a Boiler Compound. ANON. (*Metal Industry*, xiii, No. 2, 56.)—A recent order placed in this country for export of 400,000 pounds of zinc calls attention to one of the uses to which this metal has been applied abroad, which perhaps is not widely known in the United States. The order referred to above was for pure zinc in the form of plates six inches long, four inches broad, and a half inch thick. These plates had a half-inch hole bored or punched through the centre, and the method of using them is as follows: A steel rod is introduced through the side of a boiler, and these plates of zinc, together with steel or iron washers, are strung on the rod in alternate layers, so that there is constant contact between the zinc and the iron all the way across the boiler. When the boiler is in use this arrangement of the two metals constitutes an electric couple, and a galvanic current of electricity is set up inside the boiler which, it is claimed, effectively prevents not only foaming of the boiler, but also the deposition of scale. In this way the use of various materials known as "boiler compounds" is eliminated and the boiler is kept in good, clean condition for an indefinite period. There does not seem to be any reason why aluminum plates used in the same way will not produce the same results, and possibly, owing to the difference in specific gravity between aluminum and zinc, more surface may be offered for action by using aluminum.

ADDRESS TO GRADUATING CLASS, FRANKLIN INSTITUTE SCHOOL OF MECHANIC ARTS.*

BY

GEORGE A. HOADLEY, Sc.D.,

Emeritus Professor of Physics, Swarthmore College.
Member of the Institute.

No man who is in mental health ever completes his education. His condition of bodily vigor has a decided effect upon it, but nothing short of a mental breakdown or death puts an end to his acquirement of what we call an education.

There are many phases to this lifelong process, and it is a good plan for us to stop for a little, whenever we reach the end of a certain phase or part of the work, and take a look back over the path along which we have come, and forward into the undefined future, in order that we may learn the lessons that the past teaches and get a firm grasp of the hopes that the future holds out to us.

You of the graduating class of The Franklin Institute have reached the end of one of these phases in your education to-night, and it is fitting that we should consider, for a time, what education may mean.

While we are surrounded, from our earliest conscious existence, with persons and things that are our teachers, I believe that we must agree with many of the wisest men of the past and the most experienced men of the present that what we get out of our education we shall have to put into it ourselves.

This may seem to be a contradictory statement, or one that suggests an impossible condition, but it is not when once it is understood.

To put energy, enthusiasm, and perseverance into the study of any subject brings to the student a thorough comprehension of that subject and also the ability to apply its principles to the demands of the practical in everyday life. It also gives him such a grasp of the fundamentals of the subject that he can meet the unexpected demands that are sure to arise, and at the same time it enables him to find the solution for new problems that marks him as a successful man among his fellows.

---

* Delivered at closing exercises of Ninety-first Year of School, April 16, 1915.

If, on the other hand, a man undertakes his study in a half-hearted kind of way, if he takes it up as a pastime rather than as a pursuit of real importance, he will find that the knowledge he has gained on the subject is only superficial, and his ability to apply what he has learned will be so small that it will prove of little value to him or to any one else.

I am taking it for granted that the object of an education is that a man may be of greater value to himself and to his fellow-men.

I very well know that there is an education that a man can give himself that adds greatly to his ability to read and understand what others have written and to grasp the details of the inventions that others may have made. This kind of education is by no means to be despised. It adds much to the value of life for any man, and makes him more a part of the times in which he lives.

But the kind of education that The Franklin Institute believes in, is that which not only enables him to be an intelligent reader of history, but to become a helper in the making of the history of his own time; that enables him not only to understand the principles that underlie any invention, but that gives him the power to apply principles already known, in new directions, and thus to become an inventor himself; that enables him not merely to absorb what is already known for his own improvement and use, but to digest what he absorbs and to put it forth in a new dress, thus giving to the world something new in Literature, in Art, or in Science.

There is one term that is frequently used, and that is generally applied to a man who has been what is called successful in life, and that is the term "Self-made." People say of such a one, "He is a self-made man," as though that set him off in a class by himself. This is never said, as it should be as well, of one who is not a success, while it is the only thing to say of any one, for the truth is that there are no other men living except self-made men.

The very fact that the term is never used except to point out those who are successful in their endeavors is both an acknowledgment of that success and a testimony to the importance of selecting the right things upon which to expend one's energy.

The longer I live the more I am convinced that a young man who determines to secure success in life in any definite direction can secure that success, provided always that he is willing to pay the price of whole-hearted devotion, untiring energy, and a resolute putting aside of anything that does not help in securing the desired end.

If a man determines to secure wealth, he will make that his main purpose in life. If he is in haste to be rich, he will very likely risk his savings in ventures that promise with a lavish prodigality, but when it comes to the returns will probably produce nothing but loss and thus make shipwreck of his purpose. If, however, he is willing to take the sure but slow path that leads to wealth, he will lay aside each year whatever he can compel himself to save from his earnings, and will add to this sum the increase which it will bring if invested in some perfectly safe way, and he will find himself, as the years go by, with a bank account that gains from year to year with increasing rapidity.

Suppose, to take a concrete example, that a young man of twenty saves twenty-five cents per day for each working day. This makes one dollar and fifty cents per week, or seventy-eight dollars per year. Now by investing this money at five per cent. and also investing the interest each year until he is fifty years of age he will find at that time that he has saved $4819.36, while if he continues the practice until he is sixty years of age he will find himself the possessor of $8900 in cash, an amount that will provide for his ordinary expenses for the rest of his natural life if used with a reasonable amount of economy.

If this saving of twenty-five cents per day seems to be too much, let us assume that he can save five cents per day, the cost of a car fare, and at fifty years of age he will have over a thousand dollars.

These examples of what persistent saving will accomplish are not given for the purpose of magnifying the importance of saving money, but with the idea of calling attention to the fact that persistence in an undertaking is one of the most important factors in attaining success.

I have said that if a man makes up his mind to attain a certain end and is willing to pay the price he can be sure that he will succeed, and have shown how this will work out in the saving of money. The same statement is true whatever may be the end sought.

Suppose that a young man determines that he will make himself a master machinist. This means more than to become an expert workman, though it includes that as a part of the training. It means not only that he must know how to operate every kind of machine that is to be found in a well-equipped shop, but he must know how to do this with the greatest economy, and he must also know how to get out of the machine a maximum output for the power it absorbs.

He must understand the construction of the machine, study the mechanical principles through which it operates, be quick to see how it can be improved, and be able to put these improvements into practical shape. In short, he must make machines his study, and when the demand for a new form of product is brought to his attention he should be able to devise, build, and operate a new machine that will put the product on the market.

If a man determines to become a salesman, and not only that, but to become one of the best, a man who will always command a good position and salary, he will need to know much more than the story of the goods he sells. He will need to know *that*, from the smallest detail of manufacture to the various prices at which they can be put upon the market, but he will also need to know *men*, and this is his greatest need. He will probably have to put more time into a study of the men to whom he hopes to sell his goods than into a study of the goods themselves.

In this study he will require all his experience and an intimate knowledge of psychology to enable him to recognize the varying moods of his customers and to adapt himself to these uncertain moods.

The particular thing that I am trying to bring to your attention is that persistent and determined effort is the one thing that is sure to bring success, and I will cite a single authentic example.

About forty-five years ago a boy working for a neighbor at cutting and shocking corn had the good fortune to find a seedling peach tree in the fence corner on one side of the field that was filled with small but toothsome peaches. Every time that his work brought him to this side of the lot he took a seat upon the fence to rest and while doing so would eat a few of these delicious fruits. Not only did he eat the peaches, but he thought about how it had happened that the fruit of this seedling was so much sweeter and better flavored than any peach he had tasted before. He also began to suspect that the seedling tree grown from the kernel in a peach stone would not produce a peach like the one from which it came, but that it would have a flavor all its own.

He then began to wonder if it would be possible to plant a great many peach stones and finally get a peach much bigger and finer flavored than any other. Then came the resolution to coax his mother to let him have some land and to follow up this idea as best he could.

The decision changed the lonesome boy in the cornfield into a potential fruit raiser, and when he got down from the fence and went to work again he put into it the zest that comes to one who is working out a new plan.

The next year, in 1869, the boy got a better job, one that paid him $12.50 per month and his board, and out of this he saved enough to buy and set out two hundred of the best peach trees he could find.

From this time on the boy devoted his entire time to the raising of fruit, mainly peaches, and during the year ending August 1, 1912, he raised and sold over 100,000 bushels of the finest peaches in the market.

One afternoon, fifteen years ago, this man, who had spent thirty years in studying this one fruit, drove through an orchard of early peaches that had been picked and sent to market weeks before. In this orchard he noticed a seedling tree that was full of beautiful big, red peaches, and on trying one of them he found it to be a delightfully flavored freestone and that what he had been looking for for thirty years had come to him, and since that time he has devoted himself to the propagation of this magnificent peach. This man is raising and selling these trees just as enthusiastically to-day as ever, and so contagious is his enthusiasm and so great is the benefit he is conferring upon mankind by the propagation of this tree that they are being set out and cultivated by the million.

Thirty years seems to be a long time to wait for success, but when it comes in such unquestioned form and receives such cordial recognition it is well worth the waiting for.

When a young man graduates from an institution he is not usually in a position to be his own employer. As a general thing he is looking for a job, or, if you prefer it, he is trying to find a position.

I must confess I like the first way of putting it best. It has in it more of a feeling that the man who is looking for a job wants to do something, and there are very few employers who are willing to pay a man for his mere presence at the plant.

I have a feeling that no man has a right to take a position solely for the money there is in it. If he does, it is an indication that he is simply selling his time, that he is not putting himself and his interest into his work.

Suppose that you imagine yourself to be the employer. Suppose that you had spent years in developing a business and depended in a great measure upon the loyalty and interest of those in your employ to carry it on and develop it as your experience has taught you it can be developed.

Imagine the anxiety with which you would look into the face of a young man who came to you for employment, and how certainly your decision as to taking him would be determined by the impression you formed of his ability and interest, and his remaining in your employ would depend upon how well his work had carried out the opinion you had formed in that short interview.

One of the most important things in the industrial and business world to-day is the relation between the employer and the employed. Their interests should be identical and the coöperation between them should be of the most cordial type.

It is very certain that if there were no employers there would be no employment to be obtained, and no manufacturer could carry on his business without the assistance of the men who work for him.

There would be no question of this cordial coöperation if both the employer and the employed would each consider himself for a short time in the position of the other and honestly consider what he would think best to do when in that position.

The employer needs to feel the difficulty the workman finds in meeting the demands made upon him in giving his children the education that is the best legacy that he can leave them, and in furnishing for his family the comforts that mean so much in our everyday life.

The workman needs to feel the responsibility that is always with the employer to provide work for his men, to be able to meet the gripping competition under which he is always working, and the sleepless nights that he passes in trying to see how he can make enough in the business to pay his men, meet his interest, and save enough out of the returns to allow him to give his family reasonable comforts.

No man can be of the greatest use to his employer who does not take an interest in his work and who is not faithful to the trust that is imposed in him.

I know a man who for some years was in sole charge of a small gas plant, a plant that required but a single man for the greater part of the time. After a while his employers decided that they would stop the manufacture of gas for themselves and buy their supply from a large company in the neighborhood. It was arranged that my friend should go with the larger company as day watchman in charge of the grounds. He easily proved himself qualified for the place, and when the head of the company rode into the grounds one day in his automobile and proceeded to make an inspection of the plant he was held up by the watchman, who asked him what he wanted. "What do I want? Why, I am the head of the company and am looking things over."

"Do you have a permit with you?" "No, I don't need one." "Well, I don't know you, and you can't stay here without one," and the watchman drove him out of the grounds.

Now this was an experience that had never come to the employer before, but he saw that if this could happen to one who claimed to be the head of the concern, and came in the proper style for a man in that position, it would be liable to happen in the case of any one who might want to come into the grounds for improper purposes, and that watchman is now one of their most trusted employees.

Loyalty to the men who employ him and a living interest in the business in which they are engaged are qualities that are highly prized by any employer, and form a most valuable asset for the man who is looking for work.

There is no type of service that a man can render to his employer in which loyalty is not of value. I was talking the other day with one of my neighbors, a graduate of a college, who has for years held a position of large responsibility with one of the most successful business concerns of this city. In the course of the conversation he remarked that his business now took him away from home a great deal. On inquiry I found that his company had decided that it was necessary to have a representative in New York and he had been selected for the position.

Now, while this transfer is a recognition of his faithfulness and loyalty, it brings with it the discomfort of taking him away from his family and from a most comfortable home. In speaking of this he said: "Yes, it is not convenient, but when you are working for an employer you must do as he says." I believe it is this recognition of the rights and interests of his employers that has made him of so great value to them.

There can be no doubt that some of you will eventually become employers, and at that time, if not before, you will recognize the value of having the coöperation of your employees in your business.

We hear a great deal in these days about efficiency and it has come to have a restricted and harmful meaning.

I have the greatest respect for the efficiency that succeeds in getting from both men and machines the greatest output that can be obtained, provided the welfare of both is considered, but I have none whatever for a so-called efficiency that extracts the maximum output from a man at the cost of turning him into a piece of automatic machinery.

There is a greater product that can be turned out by a manufactory than the product of its machines, and that is the manhood of those who run them. That business is not worthy of support that succeeds financially at the expense of either the physical, mental, moral, or spiritual welfare of its workmen.

I have said that you who graduate from the schools of this Institute have now reached the end of one phase of your education. This, however, is a phase of your education and not the whole of it. It is unquestionably a fact that what you have learned here has made it more possible for you to carry on that education either by yourselves or with the aid of other schools and colleges.

The education that we give you here we try to make practical. A good share of what you have learned you will make immediately available, some of it you will not, and perhaps you will think it of little value, but I will venture to say that you will, at some time or other, find use for everything you have learned.

It is a striking commentary on the value of an education, that so few uneducated men ever attain prominence in the things of highest value. Those who have taken advantage of the best educational opportunities are directing the destinies of the nation.

This is shown by the fact that a very large percentage of the Judges of the Supreme Court, Senators, Representatives, and Governors of States are college graduates, while those who are not have won their positions through the service they have rendered their fellow-men while educating themselves in the college of experience.

Education is something you must get by hard work. It is something you cannot buy. You can give it away to no man, and no man can take it from you. It extends the boundaries of your mental vision, and it gives you the key with which to unlock the treasure-house of all time. To gain it, men have starved their bodies and through it they have beautified their souls. It is among the best of the gifts of the Creator, since it is a prize that any one can win.

"Natural" Electrolytic Corrosion in Soils. E. H. SCHOFIELD and L. A. STENGER. (*Elect. Rly. Journal,* xliv, 1092.)—This is a record of some laboratory experiments which are intended to prove that electrolytic corrosion of metallic structures takes place under certain conditions naturally, and is not dependent entirely on stray traction currents. There are two classes of cases which are considered. First, there is a case where a metal such as cast iron or steel contains impurities in its structure, and, secondly, there is the case of the metal, like lead, which is ordinarily considered non-corrodible, but which is none the less liable to corrosion if in contact with two soils of different compositions,—*i.e.*, containing two different electrolytes. These two cases were studied experimentally, a large number of soils being collected for the purpose of the tests, and in both cases it was established that corrosion, undoubtedly of an electrolytic nature, was set up, owing to the natural action of the soil, and quite apart from any effect which could be due to stray currents. Cast-iron samples, where corroded, were covered with a hard scale of rust and soil; the pits in the cast iron were local, and filled with carbon and black iron oxide. The lead samples showed the presence of both the gray and the brown oxides. Potential differences up to one volt were generated by placing different metals in contact with certain soils, or by placing two pieces of similar metal in contact with different soils. Photographs are also given of cast-iron and mild steel pipes, which have been pitted electrolytically in districts where no electric railways or leakage currents exist.

Semi-portable Superheated-steam Engine. (*Engineering,* xcviii, 560.)—This illustrated article describes a 100-b.h.p. "locomobile" type of engine constructed by Marshall & Co., Gainsborough. The side-by-side compound engine is mounted on the boiler top. The cylinders are in one casting with separate liners. Steam is distributed by balanced piston-valves with special spring rings driven from the crank shaft by eccentrics and rocking levers. Governing is by cut-off variation in the high-pressure cylinder. The exhaust steam passes through a tubular feed-heater to a jet condenser. The Cornish multitubular boiler is made of Siemens-Martin steel for working at 180 pounds per square inch pressure. The firebox and tubes can be removed bodily for internal examination, etc. A recent four-hour test gave the following results: Feed temperature, 120° F.; steam pressure, 188.7 pounds per square inch; steam temperature, 541° F.; superheat, 158° F.; vacuum, 27 inches; r.p.m., 206; b.h.p., 124; coal consumption, 1.47 pounds per b.h.p.-hour; calorific value of coal, 11,500 B.T.U.s; coal burnt per square foot grate area, 23.7 pounds per hour; CO_2 in flue gases, 10.9 per cent. Similar plants are made for capacities of 50 to 300 b.h.p. The special superheater is described in detail.

A New Primary Cell. E. BELLINI. (*Lumière Electr.*, xxvi, 115.)—The author draws attention to the fact that in the usual types of cell employing zinc a soluble salt forms and the zinc is liable to be deposited on the electronegative plate, thus polarizing it. He therefore sought to design a cell in which the salt formed would be insoluble. The objection to doing so is that the insoluble salt may remain upon the plate, thus increasing the internal resistance during the life of the cell. The author selected lead as his electropositive metal, and had, in order to eliminate the last-mentioned difficulty, to use it in the form of an amalgam. This he forms by adding ten per cent. of mercury to the molten lead. Carbon is used as the other plate, and the electrotype consists of the following mixture of sulphuric and nitric acids: Water, 1000 c.cm.; sulphuric acid of 66° Baumé, 80 c.cm.; nitric acid of 36° Baumé, 120 c.cm. The electromotive force is 1.25 volts. Curves are given showing the discharge obtained. In the case of a cell containing 2.6 litres of electrolyte a current varying from about 4.5 ampères down to 4 ampères was obtained during 13½ hours, and was more or less repeated after a rest of 11 hours. A further discharge of 14 hours with rather higher current was then obtained by adding a certain quantity of the mixed acids.

Uranium Ores in Madagascar. C. GROSSMANN. (*Comptes Rendus,* clix, 777.)—A mineral has been discovered at Fiadanana, Madagascar, externally resembing euxenite and containing twelve to forty per cent. U_3O_8. Its radio-activity, tested by an aluminum foil eléctroscope, is about double that of the pure oxide, thus suggesting an important source of radium.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

THE VALUE OF THE HIGH-PRESSURE STEAM TEST OF PORTLAND CEMENT.†

By R. J. Wig and H. A. Davis.

The use of high-pressure steam as a means of determining the soundness and cementing quality of Portland cement was advocated as early as 1880 by both Michaelis and Erdmenger. It has been recommended and used by others from time to time until recently, when a form of this test was advocated and introduced into specifications for the purchase of Portland cement as the Force autoclave test. Many brands of American cement would not regularly meet the requirements of this test, and its recent introduction led to a controversy between cement manufacturers and consumers. The manufacturers of Portland cement contended that this test was an abnormal one, and the behavior of a cement when so exposed was no criterion of its ultimate behavior as normally used in concrete. Furthermore, it was suggested that this test be introduced into the United States Government specification for Portland cement, and it was for these reasons that an investigation of the value of the high-pressure steam test was undertaken.

This investigation included a study of the physical properties of cements that were sound after exposure in high-pressure steam and cements that failed to meet the requirements of this test. Tests were made of the tensile and compressive strength in mortars, compressive strength in concretes, and the linear change of neat cement prisms stored in air, in water, and treated in high-pressure steam.

The qualitative high-pressure steam test consisted of subjecting a pat of neat cement, after storing for the first twenty-four hours in a damp closet, to steam at a pressure of 300 pounds per square inch for one hour, in a steam-tight boiler, the total time in the boiler being three hours. A cement was said to have passed

---

[*] Communicated by the Bureau.

[†] Abstract of Technologic Paper No. 47.

this test if the pat was hard and sound when examined after this treatment. The quantitative high-pressure steam test consisted of moulding six neat cement briquettes, storing them twenty-four hours in a damp closet, then treating three of them in steam at 300 pounds pressure for one hour in a steam-tight boiler, the total time in the boiler being three hours. The six briquettes were then broken in a cement testing machine, and a cement was said to pass the high-pressure steam test if the treated briquettes showed higher tensile strength than the untreated.

Eighteen two-barrel samples of cement, composed of seven different brands, were obtained for testing in concrete. The cement of some of these samples passed the high-pressure steam test, and the cement of other samples did not. The concretes prepared from these cements have been normally exposed to the atmosphere for two years or more and tested for compressive strength from time to time. Sufficient specimens were prepared to continue the tests for ten years.

The following is a brief summary of the results of this investigation:

The general soundness tests show that some cements mixed neat which are sound according to the standard atmospheric steam test but unsound in high-pressure steam exhibit signs of unsoundness when stored under normal conditions in dry air. This unsoundness may require nine months or more to develop in neat cement specimens.

The strength tests of mortars and concretes fail to show any difference in the cementing quality of cements that pass the high-pressure steam test and those that fail to meet the requirements of this test.

There is but small difference, if any, in the linear change of prisms made of cement that passes the high-pressure steam test and prisms made of cement that fails to meet the requirements of this test, whether stored in air or water.

Seventy per cent. of a total number of fifty-one brands of Portland cement tested passed the high-pressure steam test.

Cements normally unsound in the atmospheric or high-pressure steam tests will generally be found to be more sound than the original cement if the coarser particles are removed. While fineness is not essential to soundness it appears usually to be the coarse particles of a normally unsound cement that cause the expansive action resulting in cracking and disintegration of the hardened cement in the accelerated tests of soundness.

A cement originally unsound in the high-pressure steam test will usually be found sound if exposed to this test after aging from two to six months.

The following conclusions are drawn from the results obtained:

1. The high-pressure steam test should be made on all cements that are to be incorporated in cement mortar or concrete products that are to be cured in steam at pressures above atmospheric.

2. The high-pressure steam test may be of value as forecasting the behavior of neat cement or a very rich mortar when exposed under normal conditions in dry air, but it does not forecast the behavior of cements in concrete as normally exposed.

3. Cement passing the high-pressure steam test is not superior in cementing quality, as determined from the compressive strength of concretes, to cement that fails in this test.

4. Cement passing the high-pressure steam test does not make more permanent or durable concrete than cement which meets the requirements of the standard specifications but fails in this test.

5. Cement failing to pass the standard specification atmospheric steam test, but meeting the other requirements of the standard specifications, shows in some instances a normal strength in concrete.

6. For practical work under normal conditions of construction, the results of this investigation fail to show that the high-pressure steam test is of value as a means of determining the ultimate soundness of concrete.

THE EMISSIVITY OF METALS AND OXIDES. IV.—IRON OXIDE.

By George K. Burgess and Paul D. Foote.

[ABSTRACT]

THIS paper is a continuation of the study of the radiometric properties of metals and oxides. By the use of radiation pyrometers and the method of miscroscopic melts described in the earlier papers, the total and monochromatic emissivity ($\lambda = 0.65\,\mu$)

of iron oxide formed by heating iron in air has been determined at high temperatures.

Iron oxide in the spectral region $\lambda = 0.65\ \mu$ is almost "black," having an emissivity varying from 0.98 to 0.92 in the range 800 to 1200° C. The corrections necessary to apply to the readings of an optical pyrometer in this temperature range vary from 0 to 10° C. The total emissivity of iron oxide increases from 0.85 at 500° C. to 0.89 at 1200° C. The corrections necessary to apply to the readings of a radiation pyrometer in this temperature range vary from 30 to 50° C.

The temperature of the outside of the oxide layer is considerably different from that of the inside in contact with the metal, on account of, in part, the low thermal conductivity of the oxide and in part, undoubtedly, the actual separation of the outside oxide layer from the metal, thus forming an air gap between the two surfaces or between two surfaces of oxide, the outer one thick and the inner one thin. The drop in temperature through the oxide layer is approximately constant for various-sized samples, from small iron tubes to 100-pound rails, and increases rapidly with temperature, rising to about 100° at an outside temperature of 1100° C.

Cementing Value of Bituminous Binders. L. Kirschbraun. (*J. Ind. Eng. Chem.*, vi, 976.)—The cementing value of a binder is directly proportional to the work done in producing fracture or failure of a given unit of material. An apparatus is described by means of which strain is applied to a briquette of the material by a dynamometer travelling at a uniform speed, and the strain and elongation are measured. The briquette is drawn out until finally it either breaks or the rate of elongation becomes higher than the rate of travel of the dynamometer, so that the values recorded by the latter pass through a maximum and then return to zero. Results obtained by this method with different materials are given in tables and diagrams. The cementing value is represented by the area enclosed by a curve plotted with amounts of elongation as abscissæ and the values for the strain as ordinates; but the values for the elongation and the maximum strain must also be taken into account separately in estimating the value of a given material. In the case of bitumen for sheet asphalt pavement, it is recommended that when tested by the author's method the minimum cementing value should be 0.08 kilogramme-metre for light and 0.24 kilogramme-metre for heavy traffic, with elongations of 8 to 14 cm. and 4 to 6 cm. respectively.

THE FRANKLIN INSTITUTE

(*Proceedings of the Stated Meeting held Wednesday, April 21, 1915.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 21, 1915.

PRESIDENT WALTON CLARK *in the Chair.*

Additions to membership since last report, 6.

Mr. George H. Clamer, Chairman of the Committee on Science and the Arts, reported the condition of the committee's work.

Mr. W. S. Bartholomew, President, Locomotive Stoker Company, Schenectady, N. Y., presented a communication on "Mechanical Stoking of Locomotives." The speaker described various types of stokers, and particularly those which are now being used. The economic value of the mechanical stoker and its effect upon the labor problem were considered, as well as the benefits received by the railroad company, especially in the elimination of the physical limit set by the firemen upon the capacity of a large locomotive, which, when mechanically fired, can evaporate all of the water the injectors are able to deliver to its boiler. The effect of the use of mechanically-fired locomotives upon the movement of traffic under present operating conditions was also shown. The subject was illustrated by numerous lantern slides.

In the discussion which followed the reading of the paper, Messrs. George R. Henderson, of Philadelphia; A. L. Willsie, of Chicago; W. L. Robinson, of Baltimore; Dr. Angus Sinclair, of New York, and others participated. After a vote of thanks to the speaker the meeting adjourned.

R. B. OWENS,
Secretary.

THE FRANKLIN INSTITUTE SCHOOL OF MECHANIC ARTS.

ANNUAL REPORT OF THE DIRECTOR OF THE SCHOOL.

1914–1915.

COURSES OF INSTRUCTION.

The courses given in the ninety-first year of the School, ended April 8, 1915, were substantially the same as those given in the preceding year. Classes were formed in all the courses offered and announced in the prospectus issued last summer, and in some of the courses, notably first-year Mechanical Drawing and Mathematics, the classes were large. The courses given were: Mechanical Drawing; Architectural Drawing and Design; Freehand Drawing and Water Color; Algebra; Mensuration and Elementary Geometry; Advanced Geometry; Plane Trigonometry; Applied Mechanics and Strength of Materials; Elements of Mechanics and Machine Design; Steam Generation; Structural Design; Theoretical Naval Architecture; Practical Naval Architecture.

REGISTRATION.

The total registration in all Departments was two hundred and sixty-seven. This was lower than that of last year. From the number of requests at the beginning of the term from students for registration with deferred payment of fees on account of loss of positions and other causes it was evident that the decrease in registration was due to the then prevailing industrial conditions.

FACULTY.

Prof. William E. Bullock again officiated as Assistant Director. Prof. Clement Remington continued his charge of the classes in Architectural and Freehand Drawing. Messrs. F. H. Lobb, I. P. Pedrick, and Charles Rommel instructed in Mechanical Drawing, as last year. Mr. W. W. Twining assisted in the Department of Drawing. Prof. Simeon van T. Jester was appointed to take charge of the Department of Mathematics, in place of Prof. H. P. Tyson, who was unfortunately obliged to relinquish this work this year on account of the pressure of other work, and Mr. H. S. Detwiler assisted him. Prof. Elmer Bark continued as Professor of Mechanics, and Mr. M. M. Mark instructed in Steam and Structural Design. Prof. H. C. Towle continued in charge of the classes in Naval Architecture.

SCHOLARSHIPS.

In August, 1914, Hon. G. W. Edmonds, member of the Institute, offered to pay the tuition fees of five new scholars as an inducement to young men to enter the School. His offer was accepted by the Committee on Instruction, and an examination of young men was held and George L. Dreeman, Fred E. Miick, Joseph H. Ritchie, Wm. H. Stewart, and Geo. W. Williams were selected and are now receiving their two-year courses by Mr. Edmonds's courtesy.

In addition to these Scholarships, there were available twelve Bartol Scholarships in Drawing from the income of the B. H. Bartol Fund, and one Thorn Scholarship in each of the Departments of Mathematics, Mechanics and Naval Architecture from the Isaac B. Thorn Fund.

PRIZES.

Mr. Samuel M. Vauclain, Vice-President of the Baldwin Locomotive Works, presented a prize to be awarded to the student of best record in the Department of Mechanics, and Mr. W. D. Baldwin, President, The Otis Elevator Company, New York, N. Y., donated a prize for the student in the Department of Drawing making the best set of drawings for the year. Mr. J. B. McCall, President, Philadelphia Electric Company, and Mr. Wilfred Lewis, President, The Tabor Manufacturing Company, again donated prizes, as last year, as did the New York Shipbuilding Company. The Alumni Association continued its special prizes for students in Mechanical Drawing, Architectural Drawing, Freehand Drawing, Mathematics, Mechanics and Naval Architecture.

ATTENDANCE AND PROGRESS.

The attendance throughout the year was well above the average, and the work done was of exceptional merit in a large number of individual cases.

VISITS.

Six visits to places of engineering interest were paid on Saturday afternoons during the season, as follows: Milbourne Mills, Otto Gas Engine Works, The Curtis Publishing Company, Philadelphia Rapid Transit Company's Beach Power House, Link-Belt Company, University of Pennsylvania, Queen Lane Pumping Station, Bureau of Water. The average attendance at these visits was thirty.

HONORS.

Certificates for the satisfactory completion of a two-year course in one of the four Departments of Drawing, Mathematics, Mechanics, and Naval Architecture are this year awarded to sixty-one students, an increase of sixteen over last year. The names of graduates for the season 1914–1915 are appended, as also are the names of those students to whom are awarded the scholarships and prizes indicated above, and of those granted certificates of Honorable Mention for regularity of attendance and proficiency in class work.

I desire to express my appreciation of the sustained coöperation of those members of the faculty who continued in the School from the previous year, and also of the very efficient work of the new members, and I sincerely hope that when the ninety-second year opens in September, 1915, they will all resume their duties, so that the coming year may be as successful as the one just closed.

Respectfully submitted,

WM. H. THORNE,
Director.

LIST OF GRADUATES, ETC., 1914–15.

MECHANICAL DRAWING.

Wilbur S. Austin
Frederick A. Bach
Branson Barnes
Henry J. Bohn
William H. Buchy
Frank Christen
Edwin S. Elder
Jonathan Geiger
Alfred R. Godfrey
Henry Graul
Thomas J. Hackett
Emery J. Hadik
Harry Haering
Joseph Hecking, Jr.
Robert B. McArdle
John McGinnis, Jr.
Vincent Martin
Theodore T. Marville, Jr.
John Morris, Jr.
Charles W. Paarz

Irvin M. Pfeiffer
George M. Pfundt
Edward J. Pritchard, Jr.
George Richter
Frank J. Sarlo
Charles Schneider
Welling G. Schrack, Jr.
James P. Shinn
Herbert Sommermann
Harry W. Whitson
Howard G. Zeyher

ARCHITECTURAL DRAWING.

John Clark Good
Fred Stadtler
Warren G. Tilton

FREEHAND DRAWING AND WATER COLOR

Howard A. Graul
Rufus Haley

MATHEMATICS.

Clarence E. Baittinger
John J. Bowen
Robert G. Cook
Arthur H. Eilitz
Albert Forster, Jr.
Henry Graul
Emery J. Hadik
Harry Haman
Frederick Heinze
Herbert Jayes
Samuel King
Leon Liberman
John McGinnis, Jr.
John G. Merkh
Thomas M. Morrissey
Abraham Perlman
Frank Powell
G. H. Pratley

MECHANICS.

William Keller
John A. Schneider
Raymond S. Wood
Albert F. Wunderlich

NAVAL ARCHITECTURE.

Lawrence Hoban
Ridgley Sweeney
Frederick C. Whitney

EDMONDS SCHOLARSHIPS.

WINTER AND SPRING TERMS.

George L. Dreeman,
Drawing
Fred E. Miick,
Mathematics
Joseph H. Ritchie,
Drawing
William H. Stewart,
Mechanics
George W. Williams, Jr.,
Drawing

BARTOL SCHOLARSHIPS.

Department of Drawing.

WINTER TERM.

Sophie Colles,*
Freehand
Harry Haering,
Mechanical

---

* Fourth Year.

Joseph Hecking, Jr.,
Mechanical
Vincent Martin,
Mechanical
Frank B. Otto,
Architectural
Fred Stadtler,
Architectural

SPRING TERM.

Ellis Ayars,
Mechanical
Charles W. Bowne,
Mechanical
Frank B. Otto,
Architectural
Charles Schneider,
Mechanical
Fred Stadtler,
Architectural
Alfred G. Windstein,
Freehand

THORN SCHOLARSHIPS.

WINTER TERM.

Fred W. Grube,
Mathematics
J. L. Starr,
Mechanics
Frederick C. Whitney,
Naval Architecture

SPRING TERM.

Raymond Mattis,
Mathematics
Herbert Rovno,
Mechanics
Lawrence Hoban,
Naval Architecture

MR. W. D. BALDWIN'S PRIZE.

DRAWING.

Harry Haering

MR. J. B. McCALL'S PRIZE.

MATHEMATICS.

John G. Merkh

MR. S. M. VAUCLAIN'S PRIZE.

MECHANICS.

Raymond S. Wood

MR. WILFRED LEWIS'S PRIZE.

MECHANICS.

E. Victor Cooley

NEW YORK SHIPBUILDING COMPANY'S PRIZE.

NAVAL ARCHITECTURE.

Frederick C. Whitney

ALUMNI ASSOCIATION OF THE FRANKLIN INSTITUTE'S PRIZES.

AWARDED TO GRADUATES.

Harry Haering,
Mechanical Drawing
Fred Stadtler,
Architectural Drawing
Sophie Colles,*
Freehand Drawing
John McGinnis, Jr.,
Mathematics
Albert F. Wunderlich,
Mechanics
Ridgley Sweeney,
Naval Architecture

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, April 7, 1915.*)

Hall of The Franklin Institute,
Philadelphia, April 7, 1915.

Mr. G. H. Clamer *in the Chair.*

The following reports were presented for first reading:

No. 2613.—Anderson's Rolled Gear Machine.

No. 2633.—Owens's Bottle Making Machine.

The following report was amended and adopted:

No. 2597.—Wheeler's Escalator. Edward Longstreth Medal of Merit to Mr. George A. Wheeler.

R. B. Owens,
Secretary.

AWARD OF THE JOHN SCOTT LEGACY MEDAL AND PREMIUM.

The City of Philadelphia, acting on the recommendation of The Franklin Institute, has awarded the John Scott Legacy Medal and Premium to Herbert Alfred Humphrey, of London, England, and to Cav. Ing. Alberto Cerasoli, of Rome, Italy, for the Humphrey Pump, a device for raising water by the direct application of the explosive energy of a mixture of combustible gas and air. In the pump, the momentum of a moving column of water is utilized to draw in and compress in a suitable chamber a charge of the gas mixture whose explosion raises the water.

The first installation of a Humphrey Pump was made at Dudley Port, in England, in 1909. Three years later, four pumps, each having a capacity of 40,000,000 gallons per day, and one pump of 20,000,000 gallons per day, were installed by the London Metropolitan Water Board. Tests subsequently made on these pumps gave an average fuel consumption of 0.904 pound anthracite coal per pump horse power hour.

---

* Fourth Year.

AWARD OF THE EDWARD LONGSTRETH MEDAL OF MERIT.

The Edward Longstreth Medal of Merit has been awarded to the late Mr. George A. Wheeler for his Escalator. This invention is an inclined elevator for transporting persons from one level to another. It consists of an endless system of stairs or steps having risers and treads, together with top and bottom landings. A framework provided with tracks supports the stairs, and the system is driven by proper mechanism. Passengers are guided on and off the landings by suitable means for safety, and a travelling handrail is provided for comfort. The basic invention was first disclosed in a patent granted to Mr. Wheeler in 1892, and a number of patents were subsequently issued to him for improvements and developments.

SECTIONS.

Section of Photography and Microscopy.—A meeting of the Section was held in the Hall of the Institute on Thursday, March 25, at 8 P.M.

Dr. George A. Hoadley presided.

Mr. Louis E. Levy, member of the Institute, delivered a lecture, entitled "Recent Advances in the Techno-graphic Arts."

The speaker reviewed the progress of the techno-graphic arts from the time of the introduction of the photomechanical process of reproduction of drawings. He showed how this introduction preceded even that of the daguerreotype. He described the fundamental operations of the processes of photolithography, collotype, phototype, and stereotype work, giving examples of each by the aid of lantern slides. He then considered the halftone processes and their applications, concluding with a description of the recent rotary photogravure method. During the course of his remarks, the speaker showed photographs of the principal workers in the field of mechanical reproduction of drawings and photographs, and reviewed the effect of the work of each on the progress of the art.

A rising vote of thanks was extended the speaker.

Adjourned. WILLIAM E. BULLOCK,
Acting Secretary.

Electrical Section.—A joint meeting of the Section and of the Philadelphia Section of the American Institute of Electrical Engineers was held in the Hall of the Institute on Thursday, April 1, at 8 P.M.

Mr. H. F. Sanville presided.

Dr. G. F. Stradling, member of the Institute, presented a communication, entitled "Modern Theories of Magnetism."

Pierre Curie published, in 1895, the results of his experiments relating susceptibility of both dia- and paramagnetic substances to magnetizing force and to temperature.

Ten years later Langevin developed a theory of magnetism based on the modern conception of the atom,—that is, an atom consisting of rotating electrons. This agreed with the results of Curie's experiments.

Pierre Weiss extended Langevin's theory, and introduced the idea of a magnetic field within the magnetized substance resulting from the action of the elementary magnets composing it. The strength of this internal field is calculated to be enormous, in some instances reaching to millions of gausses.

Weiss, from a study of the saturation phenomena of ferromagnetic substances near the absolute zero, has been able to determine the magnetic moment of the individual atom in a number of cases. These moments, when compared, are found to be practically all whole-number multiples of a certain quantity. To this quantity he has applied the name "magneton." An atom of iron has a magnetic moment of eleven magnetons, while for an atom of nickel the same quantity in three magnetons. The experimenter suggests that the magneton is a constituent of the atoms of all kinds, just as are electrons.

A vote of thanks was extended the speaker.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held in the Hall of the Institute on Thursday, April 8, 1915, at 8 P.M.

Mr. George R. Henderson, president of the Section, occupied the chair.

Mr. H. H. Quimby, C.E., Chief Engineer, Department of City Transit, Philadelphia, Pa., delivered a lecture, entitled "Rapid Transit Problems in Philadelphia." With the aid of numerous lantern slides the speaker conveyed an idea of the present directions and volume of transit in the city of Philadelphia and of the future needs of the city for greater facilities for quick and direct local transit. He reviewed the various proposals made to supply these needs, concluding with a detailed description of the plan recently recommended to City Councils for adoption. He illustrated the routes suggested in this plan and the types of structure, and explained the method of financing.

A vote of thanks was extended the speaker and the meeting adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

Electrical Section.—A joint meeting of the Section and the Philadelphia Section of the American Institute of Electrical Engineers was held in the Hall of the Institute on the evening of Thursday, April 15, 1915, at 8 o'clock.

Mr. W. C. L. Eglin, president of the Institute's Section, occupied the chair.

Dr. Charles P. Steinmetz, Consulting Engineer, General Electric Company, Schenectady, N. Y., delivered a lecture, entitled "Control and Protection of Electric Systems," in which he discussed the nature of different disturbances to which electrical systems are exposed, such as excess current and voltage, abnormal and excessive frequencies, and considered methods of control, suppression, and elimination of these disturbances.

A vote of thanks was extended the speaker and the meeting adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, March 10, 1915.*)

LIFE.

MISS HARRIET BLANCHARD, 1511 Walnut Street, Philadelphia, Pa.
MR. F. LYNWOOD GARRISON, 1019 Clinton Street, Philadelphia, Pa.

(*Stated Meeting, Board of Managers, April 14, 1915.*)

RESIDENT.

MR. GOUVERNEUR CADWALADER, 1710 Locust Street, Philadelphia, Pa.
MR. SAMUEL LEONARD KENT, JR., Manayunk, Philadelphia, Pa.

NON-RESIDENT.

MR. E. G. EBERLE, 1004½ Commerce Street, Dallas, Texas.
MR. W. WALLACE MCKAIG, Cumberland, Md.
MR. JAMES H. WAHL, 44 West One Hundred and Thirty-Fourth Street, Whitestone, N. Y.
MR. DAVID H. WILSON, JR., Erie Railroad Company, 50 Church Street, New York, N. Y.

CHANGES OF ADDRESS.

COL. GEORGE L. ANDERSON, 975 Hamilton Avenue, Palo Alto, Cal.
MR. WILLIAM H. BALLS, Southern High School, Broad and Jackson Streets, Philadelphia, Pa.
MR. DANIEL CHRISTY, 4927 Haverford Avenue, Philadelphia, Pa.
MR. S. B. ECKERT, 2024 DeLancey Street, Philadelphia, Pa.
MR. A. D. EDGERTON, Gardiner, Douglas County, Ore.
MR. S. S. EVELAND, 1108 South Forty-seventh Street, Philadelphia, Pa.
MR. JOHN G. FELTON, 18 East Fulton Street, Gloversville, N. Y.
MR. J. KEARSLEY M. HARRISON, 127 Township Line, Jenkintown, Pa.
MR. DAVID W. JAYNE, Barrett Manufacturing Company, 17 Battery Place, New York, N. Y.
MR. WILLIAM B. KEEFER, care of American Rubber Reclaiming Company, 406 Rittenhouse Street, Germantown, Philadelphia, Pa.
MR. E. A. MULLER, 839 Mitchell Avenue, Avondale, Cincinnati, Ohio.
MR. F. W. SALMON, 516 Twentieth Street, Birmingham, Ala.
MR. L. H. THULLEN, 85 Hick Street, Brooklyn, N. Y.

NECROLOGY.

Philip Henry Holmes was born at Gardiner, Maine, in 1845, and was educated in the public schools of his native place. He was an artist and an inventor, and in the latter connection he devoted particular attention to the production of machines for making dry fibre for paper pulp, to the fibre stopper for bottles, the graphite bearing, and the water wheel. For his invention of the oilless graphite bearing he was awarded the Institute's Elliott Cresson Medal in 1892. He became a life member of the Institute in 1891.

Mr. Holmes died on March 28, 1915.

Colonel Mark Richards Muckle was born in Philadelphia in 1825, and died on March 30, 1915. He was educated in the public schools of this city, and at the age of seventeen entered the office of the *Philadelphia Public Ledger,* where he rose from the position of clerk to that of treasurer. His active connection with this newspaper continued for fifty-six years.

Colonel Muckle took a prominent part in public affairs at an early age. He became connected with the order of Odd Fellows and with the Masonic order, in both of which he rose to offices of the highest distinction. His ability to address audiences in German made him popular with the German societies in this country. For his able services to German relief organizations he was decorated by the Kaiser with the order of the Red Eagle.

He was the first to suggest the holding of the Centennial Exhibition, and he took an active part in helping to secure the location of the exhibition in Philadelphia.

Colonel Muckle became a member of the Institute in 1853.

Mr. T. Jefferson Cope, 3244 North Fifteenth Street, Philadelphia, Pa.
Mr. Stephen Darlington, 50 North Twenty-third Street, Philadelphia, Pa.

LIBRARY NOTES.

PURCHASES.

Bakenhus, Knapp and Johnson.—The Panama Canal. 1915.
Bragg, W. H.—Studies in Radioactivity. 1912.
Coffin, J. G.—Vector Analysis. 1911.
Croft, T.—Wiring of Finished Buildings. 1915.
Dadourian, H. M.—Analytical Mechanics. 1913.
Dawe, E. A.—Paper and its Uses. 1914.
Dickson, L. E.—Elementary Theory of Equations. 1914.
Eucken, A., ed.—Die Theorie der Strahlung und der Quanten. 1914.
Galitzin, B.—Vorlesungen über Seismometrie. 1914.
Greenhill, A. G.—Applications of Elliptic Functions. 1892.
Grünwald, J.—Raw Materials for the Enamel Industry. 1914.
Hausmann, E.—Telegraph Engineering. 1915.
Henderson, G. R.—Cost of Locomotive Operation. 1906.
Howe, M. A.—Masonry. 1915.
Landolt and Börnstein.—Physikalisch-chemische Tabellen. 1912,
Laws, B. C.—Stability and Equilibrium of Floating Bodies. 1914.
Matthews, E. R.—Coast Erosion and Protection. 1913.
Metcalf and Harrison.—American Sewerage Practice. 1915.
Underwood and Sullivan.—Chemistry and Technology of Printing Inks. 1915.

GIFTS.

Ajax Manufacturing Company, Reference Book and Catalogue of Hot Metal Working Machines. Cleveland, Ohio, no date. (From the Company.)

American Society of Civil Engineers, Constitution and List of Members, 1915. New York, no date. (From the Society.)

American Tap and Die Company, Catalogue No. 5 of "Adamantine" Threading Tools. Greenfield, Mass., no date. (From the Company.)

Burrows, C. H., Text-book "Oxy-acetylene Welding and Cutting." No place, no date. (From the Vulcan Process Company, Minneapolis, Minn.)

Byers, John F., Machine Company, Catalogue No. 21 of Hoisting Equipment. Ravenna, Ohio, no date. (From the Company.)

Canada Department of Mines, "Report on the Non-metallic Minerals Used in the Canadian Manufacturing Industries," "Peat, Lignite, and Coal." Ottawa, 1914. (From the Department.)

Canada Department of Public Works, Minister's Report, vol. 1, 1914. Ottawa, 1915. (From the Department.)

Central University of Kentucky, Catalogue of The Centre College, 1914–15. Danville, no date. (From the University.)

Connecticut Public Utilities Commission, Report, 1914. Hartford, 1915. (From the Commission.)

Cutter, George, Company, General Catalogue No. 12 of Electrical Lighting and Wiring Devices. South Bend, Ind., no date. (From the Company.)

Delaware College, Annual Catalogue, 1914–15. Newark, Del., no date. (From the College.)

Deming Company, Catalogue J of Pumping Machinery. Salem, Ohio, no date. (From the Company.)

Harbison Walker Refractories Company, "A Study of the Malleable Furnace." Pittsburgh, Pa., no date. (From the Company.)

Hobart College, Catalogue 1914–15. Geneva, N. Y., 1915. (From the College.)

Illinois State Geological Survey, Bulletin No. 29, "Purchase and Sale of Illinois Coal on Specification." Urbana. 1914. (From the Survey.)

Kaiser, J., "Systematic Indexing," The Card System Series, vol. ii. London, 1911. "Le Systeme de la Carte au Bureau." Paris, 1914 (From the Author.)

Kentucky Geological Survey, Report, series iv, vol. ii, part 1. Frankfort, 1914. (From the Survey.)

Limbert, George B., & Company, Catalogue C of Steam Goods. Chicago, 1915. (From the Company.)

Main, Charles T., Industrial Plants, vol. ii. Boston, no date. (From Mr. Charles T. Main.)

Maple City Manufacturing Company, General Catalogue No. 14 of Oilers. Monmouth, Ill., no date. (From the Company.)

Michigan Board of Agriculture, Report. Lansing, 1914. (From the Board.)

Milwaukee Concrete Mixer Company, Catalogue of Mixers and Pavers. Milwaukee, Wis., no date. (From the Company.)

Music Trades Company, "The Piano and Organ Purchaser's Guide for 1915." New York, no date. (From the Company.)

Mysore Meteorological Department, Report on Rainfall Registration, 1913. Bangalore, India, 1914. (From the Department.)

National Lamp Works, Bulletin of Engineering Department on Illumination. No place, no date. (From the Works.)

New Bedford Water Board, Forty-fifth Annual Report, 1914. New Bedford, Mass., 1915. (From the Board.)

New York Bureau of Explosives, Report of the Chief Inspector, New York, 1915., (From Col. B. W. Dunn.)

New York, New Haven and Hartford Railroad Company, Forty-third General Statement. New Haven, 1914. (From R. D. Jenks, Esq.)

North Carolina Geological and Economic Survey, Biennial Report of the State Geologist, 1913-14. Raleigh, 1915. (From the Survey.)

Pennsylvania Adjutant-General, Report, 1910. Harrisburg, 1914. (From the State Librarian.)

Pennsylvania Commissioners of Sinking Fund, Report, 1914. Harrisburg, 1915. (From the State Librarian.)

Pennsylvania Department of Grand Army of the Republic, Forty-eighth Annual Encampment. Harrisburg, 1914. (From the State Librarian.)

Pennsylvania State Librarian, Report, 1914. Harrisburg, 1915. (From the State Librarian.)

Pennsylvania Water Supply Commission, 1913. Harrisburg, 1914. (From the State Librarian.)

Raymond Brothers Impact Pulverizer Company, Catalogue No. 11 of Grinding, Pulverizing and Separating Machinery. Chicago, 1914. (From the Company.)

Republica Oriental del Uruguay, Anuario Estadistico, Anos 1909-10. Montevideo, 1914. (From the Director General.)

Springfield Board of Water Commissioners, Forty-first Annual Report, 1914. Springfield, Mass., 1915. (From the Board.)

Steel Company of Scotland, Section Describing Manufactures. Glasgow, 1913. (From the Company.)

Street, R. R., & Company, Incorporated, Catalogue No. 15 of Modern Approved Appliances for the Transmission of Power, Machine Shop Specialties. Chicago, no date. (From the Company.)

Sydney University Engineering Society, Proceedings, 1912. Sydney, N. S. W., no date. (From the Society.)

U. S. Naval Observatory, The American Ephemeris and Nautical Almanac, 1917. Washington, 1915. (From the Observatory.)

University of Illinois, Report. Urbana, 1914. (From the University Library.)

University of North Dakota, General Catalogue, 1914-15. University, no date. (From the University.)

University of Virginia, Catalogue, 1914-15. Charlottesville, 1915. (From the University.)

Vermont Attorney-General, Report. Montpelier, 1914. (From the State Librarian.)

Vermont Board of Education, Report. Montpelier, 1914. (From the State Librarian.)

Vermont Lake Champlain Tercentenary Commission, Final Report. Montpelier, 1914. (From the State Librarian.)

Vermont Commissioner of Agriculture, Sixth Annual Report. Montpelier, 1914. (From the State Librarian.)

Vermont Commissioner of Taxes, Report. Montpelier, 1914. (From the State Librarian.)

Vermont Factory Inspector, Report. Montpelier, 1914. (From the State Librarian.)

Vermont Free Public Library Commission, Tenth Report. Montpelier, 1914. (From the State Librarian.)

Vermont Legislative Directory. Montpelier, 1915. (From the State Librarian.)

Vermont Soldiers' Home, Report. Montpelier, 1914. (From the State Librarian.)

Vermont Permanent School Fund, Fourth Report. Montpelier, 1914. (From the State Librarian.)

Vermont Public Documents. Montpelier, 1914. (From the State Librarian.)

Vermont Public Service Commission, Fourteenth Report. Montpelier, 1914. (From the State Librarian.)

Vermont State Board of Health, Report. Montpelier, 1913. (From the State Librarian.)

Vermont State Board of Medical Registration, Fifth Report. Montpelier, 1914. (From the State Librarian.)

Vermont State Highway Commissioner, Eighth Report. Montpelier, 1914. (From the State Librarian.)

Vermont State Geologist, Report. Montpelier, 1914. (From the State Librarian.)

Vermont State Hospital for the Insane, Thirteenth Report. Montpelier, 1914. (From the State Librarian.)

Vermont State School of Agriculture, Second Report. Montpelier, 1914. (From the State Librarian.)

Vermont Superintendent of Education, Forty-third Report. Montpelier, 1915. (From the State Librarian.)

Vermont Supervisors of the Insane, Report. Montpelier, 1914. (From the State Librarian.)

Vidal, Leon, Traite Pratique de Photochromie. Paris, 1903. (From Mr. Lucien E. Picolet.)

Whiting Foundry Equipment Company, General Catalogue of Cranes and Air Hoists. Harvey, Ill., no date. (From the Company.)

Williams, J. H., & Company, Catalogue of Iron, Steel, Copper, Bronze, and Aluminum Drop-Forgings. Brooklyn, no date. (From the Company.)

Yale University, General Catalogue, 1914–15. New Haven, 1915. (From the University.)

PUBLICATIONS RECEIVED.

Hancock's Applied Mechanics for Engineers, revised and rewritten by N. C. Riggs, Professor of Theoretical and Applied Science in the Carnegie Institute of Technology. 441 pages, illustrations, 12mo. New York, The Macmillan Company, 1915. Price, $2.40.

Chemistry of Familiar Things, by Samuel Schmucker Sadtler, S.B. 320 pages, illustrations, plates, 8vo. Philadelphia, J. B. Lippincott Company, no date. Price, $1.75.

Canada Department of Mines, Mines Branch: Peat, Lignite and Coal: Their Value as Fuels for the Production of Gas and Power in the By-product Recovery Producer, by B. F. Haanel, B.Sc. 261 pages, illustrations, tables, plates, maps, 8vo. Report on the Non-metallic Minerals Used in the Canadian Manufacturing Industries, by Howells Fréchette, M.Sc. 199 pages, tables, 8vo. Ottawa, Government Printing Bureau, 1914.

Pennsylvania Topographic and Geologic Survey: Biennial Report for the two years ending June 1, 1914. 232 pages, maps, 8vo. Harrisburg, State Printer, 1914.

Carnegie Institution of Washington: Annual Report of the Director of the Department of Terrestrial Magnetism. [Extracted from the Year Book No. 13 for the year 1914, pp. 298–332, plates 5, 6, 7.] 37 pages, illustrations, map, 8vo. Washington, no date.

Mineral Resources of the Philippine Islands for the Year 1913. Issued by the Division of Mines, Bureau of Science. 71 pages, illustrations, plates, map, 8vo. Manila, Bureau of Printing, 1914.

U. S. Bureau of Mines: Technical Paper 99, Probable Effect of the War in Europe on the Ceramic Industries of the United States, by A. S. Watts. 15 pages, 8vo. Washington, Government Printing Office, 1915.

U. S. Bureau of Standards: Circular No. 35, 2d edition, Melting-points of Chemical Elements, and Other Standard Temperatures. 2 pages, 8vo. Washington, Government Printing Office, 1915.

Calorimetric Methods. W. P. WHITE. (*Amer. Chem. Soc. Journ.*, xxxvi, 2313.)—This is the last of a series of papers on calorimetric measurements. In the "Method of Mixtures" a precision approaching or reaching 0.1 per mille, though somewhat unusual, is often desirable. The author describes its attainment as especially easy with a two-calorimeter installation, which secures the convenience and high precision of differential thermo-electric temperature measurement. This is the only advantage of the two-calorimeter arrangement, the diminution of heat-loss error being largely illusory. If instead a vacuum-jacketed flask is used for the comparison calorimeter, there is a gain in accuracy and convenience. The necessary temperature observations may be made as simple as with the twin-calorimeter arrangement by means of a special thermo-electric combination. A completely enclosing jacket of uniform temperature is necessary for this method, but this is no loss, as such a jacket is necessary for high precision with any method. This method is quite as effective with a jacket round each calorimeter, and therefore with adiabatic methods. The present method is especially advantageous for observations of great absolute precision and for use in cases where rapidity and facility in making varied observations are required.

CURRENT TOPICS

Tests of Vanadium Steel Rails. (*Eng. Record,* lxx, 450.)—The American Vanadium Steel Company has had several heats of basic open-hearth steel, to which vanadium has been added, rolled into rails for purposes of test. It has been found that the addition of vanadium to rail steels increases the elastic limit, the ductility, resistance to alternating stresses, hardness, and resistance to wear. Its use does not demand any alteration in the rolling-mill practice; in fact, the yield of rails from the ingots is likely to be increased owing to a decreased tendency towards cracking and tearing in the rolls. Compared with ordinary, plain carbon steels, vanadium steel shows a lessened tendency to segregate, resulting in a denser and more uniform product. The most suitable percentage composition for vanadium rail steels is as follows: Carbon, 0.45 to 0.60; Si, over 0.10; Mn, 1.00 to 1.25; P, not over 0.05; S, not over 0.05; V, an addition of 4 pounds per gross ton.

By the addition of vanadium it is possible to use rail steels of lower carbon content, which will reduce the danger of the production of internal fissures in rolling.—*The Iron Age.*

Electrolytic Oxygen in St. Louis. Anon. (*Sci. Amer.,* cxii, No. 2, 47.)—A number of plants in St. Louis, Mo., are producing commercial oxygen electrolytically. A ten to fifteen per cent. solution of potassium hydroxide or sodium hydroxide is employed. Through this a current of electricity is passed, and the oxygen that collects at one electrode is trapped and led off to a compressor, while the hydrogen is permitted to escape. If we, in this country, showed anywhere near the aëronautic activity of European countries the hydrogen would also be collected and used for the inflation of balloons.

The Most Powerful Electric Passenger Locomotive. Anon. (*Sci. Amer.,* cxi, No. 25, 503.)—During the year sixteen powerful electric passenger locomotives have been placed in service on the main lines of the New York Central Railroad. They are the most powerful electric passenger locomotives in existence, and each is capable of hauling a train of fourteen steel Pullman cars continuously at a sustained speed of sixty miles per hour; while with lighter trains a maximum speed has been attained with these locomotives of eighty-five miles per hour; these speeds have been accomplished frequently on the experimental track of the company near Schenectady. All the wheels of the locomotives, including those on the leading and trailing trucks, carry motors the whole weight being thus available for producing tractive effort.

Rolling-mill with Geared Turbine Drive. (*Mech. Eng.*, xxxiv, 492.)—This article, illustrated with plan and elevation, describes the first geared turbine to drive a rolling-mill in America, the only one previous to this being at the works of J. Dunlop & Co., Calderbank, Scotland, where a 750-horse-power, mixed-pressure turbine operates at 2000 r. p. m. with two-stage reduction to 375 and 70 r. p. m. The maximum loss in the gear is said to be less than 2 per cent. At the Carpenter Steel Company's works, Reading, Pa., a three-high roughing mill was formerly driven by a 36 x 36-inch simple slide-valve condensing engine at 60 to 100 r. p. m. A mixed-pressure turbine has now been installed in place of the engine, designed to work on the exhaust of a 22-inch and 40 x 48-inch stroke, cross-compound engine which drives one 8-inch and two 10-inch finishing mills by belt. When working on exhaust steam at 3 pounds per square inch and 27 inches vacuum the turbine is to develop 350 horse-power at 70 to 100 r. p. m. at the mill shaft, and is not to take more than 26 pounds of steam per b.h.p.-hour measured after second gear reduction. At 120 pounds pressure the steam consumption at 350 b.h.p. is not to exceed 17½ pounds per b.h.p.-hour. On both high- and low-pressure steam 600 b.h.p. is to be developed, and on high-pressure steam only 600 horse-power must be the output, with not more than 15.7 pounds steam per h.p.-hour.

The reduction gear is two-stage, double-helical, reducing from 5000 to about 500 r. p. m. and then to between 60 and 100 r. p. m. The gear teeth are involute, 45° angle, cut in rolled steel bands shrunk on cast-iron centres; the pinions are chrome-nickel steel forgings. The engine fly wheel, weighing 47,600 pounds, was left in place, and the connecting rod only removed. A distance piece, which also serves as a flange of the flexible coupling, was bolted to the crank disk. A multi-port valve adjacent to the turbine l. p. throttle prevents vacuum from backing up into the engine exhaust, and so prevents air being drawn in through glands and interfering with condenser action. The condenser is of the Schutte-Körting multi-jet type, with automatic relief to atmosphere; with water at 72° F. it maintains 28.2 inches vacuum (bar 29.78 inches). The cost of the turbine gear, condenser, piping, circulating pump, valves, etc., was approximately £5000, including erection. The saving through better economy by its use has been about £3000 per annum.

Transformation of Yellow into Red Phosphorus. KUSPERT. (*Z. Physik. Chem. Unterricht*, xxvii, 102.)—A minute particle of phosphorus is placed on a thin layer of candle tallow on a microscopic slide, and over this is placed a cover-glass. This is gently heated; the phosphorus melts, sinking into the tallow. After concentrating light upon the phosphorus the color is seen through the microscope gradually to change first to orange, then to red. This is accompanied by a melting of the tallow, which shows that an exothermal change takes effect.

Production of Neon and Helium by the Electric Discharge. J. N. COLLIE and H. S. PATTERSON and I. MASSON. (*Roy. Soc. Proc.,* Ser. A, xci, 30.)—Elaborate tests have been made with special forms of discharge tube. A few of these are described with the aid of diagrams. A great many of the experiments yielded negative results, for as yet unexplained reasons. Tentative suggestions are made as to why Strutt's work proved unsuccessful, and it is noted that Strutt's results are in opposition not only to many of the results obtained by the present authors, but also to those of J. J. Thompson, which appear substantially to corroborate the authors' results by an independent method. Although the source of the helium and neon has not been as yet discovered, it appears, from careful experiments now made, fairly certain that these gases were not previously contained in the materials of the tubes: and other experiments show that permeation from the air through the walls of the discharge tubes appears to be equally improbable.

Tests of Substitutes for Gasoline (*Petrol*). J. A. MOYER. (*Power,* xl, 569.)—Generally speaking, gasoline or petrol is the only fuel used for automobiles, while enormous quantities are required for farm tractors, as well as for stationary and marine engines of all types. The investigations described by the author were conducted during the past year at the Engineering Experiment Station of the Pennsylvania State College to determine the applicability of (1) paraffin, (2) alcohol, (3) motor spirit, and (4) mixtures of petrol and paraffin as substitutes for petrol in engines. Most important results as regards the effect of the injection of water and air on the capacity and the economy of the engines were also obtained, and tests and experiments to determine the underlying reasons for the peculiar action of this water, when sprayed into the combustible mixture before it enters the cylinder, are being continued. The tests were made on a four-stroke-cycle stationary type of water-cooled engine, designed particularly for operation with petrol. The cylinder bore was 6¾ by 10-inch stroke, and governing was by the "*hit and miss*" method.

The primary object was to determine the maximum power and fuel consumption for each of the fuels used, first without injecting water into the fuel-intake pipe, and later with water injection. It is well known that the injection of water is effective in preventing so-called pre-ignition, especially with fuels like paraffin, which is prone to produce excessive "*pounding*" in the cylinder when running under heavy load. It has been contended that the water injected with the fuel, since it becomes superheated steam, would have a beneficial effect, both as regards the maximum power obtained and the fuel consumption. The tests showed that the maximum horsepower of the engine was considerably increased, especially when paraffin was used for fuel, but in all cases with a sacrifice of economy;

that is, the fuel consumption per horse-power-hour was considerably greater with water injections. These tests were made with a carburettor in which the fuel was discharged under pressure in a fine vapor from a special spraying device. The carburettor was effectively heated with the exhaust gases, and after the engine was once heated uniformly its operation was little affected by varying the amount of heating of the mixture in the carburettor.

The amount of water injected was regulated by hand and a needle valve, in every case just enough being injected to prevent unusual pounding. Ignition-timing in this series was practically the same for all tests. Details are then given of the test results with and without water injection: (1) with paraffin, (2) with petrol and paraffin mixed in equal proportions, (3) with motor spirit, (4) with petrol, (5) with alcohol.

Alcohol as a Substitute for Benzine for Driving Motor Cars. W. HEMPEL. (*Z. Angew. Chem.*, xxvii, 521.)—In 1912 Germany produced 179,800 tons (metric) of benzine; in 1913, 160,000 tons of benzol, of which 50,000 tons were exported to France; and in 1912–1913, 3,753,265 hl. of alcohol. All motor cars in Berlin have been adapted to use alcohol as well as benzine. The following are the respective heats of combustion of the different substances tried in the experiments: Benzine, 9500–10.500; pure benzol, 10,260; commercial ninety per cent. benzol, 9550–10,000; pure alcohol, 7402; ninety-five per cent. alcohol, 5875; and pure naphthalene, 9628.3 Calories per kilogramme. Alcohol denatured with one to twenty per cent. of benzol is much more suitable for motor engines than that containing wood alcohol or pyridine. According to Dieterich, a mixture of one volume of petroleum spirit with two volumes of benzol is particularly suitable for this purpose. After suitable regulation of the tubes of a Lyma carburettor the following mixtures could be used: (1) a mixture of four volumes of ninety-five per cent. alcohol and one volume of ninety per cent. benzol containing 200 grammes of naphthalene per litre; (2) four volumes of ninety-five per cent. alcohol and one volume of crude benzol containing 200 grammes of naphthalene per litre; (3) four volumes of ninety-five per cent. alcohol and one volume of light coal-tar oil containing 200 grammes of naphthalene per litre. In a long run eighteen litres of mixture No. 1 gave the same result as fifteen litres of ordinary petrol. Only oils purified by sulphuric acid and alkali should be used for this purpose. There is also a possibility of using a solution of acetylene in acetone (which dissolves thirty-one volumes) or alcohol (six volumes). The use of pure alcohol tends to produce rust in the engine.

Cutting and Welding with the Oxyacetylene Torch. ANON. (*Amer. Mach.*, xlii, No. 8, 316.)—In a general review of the process of oxyacetylene cutting and welding delivered before the Illinois

Gas Association it is stated that from the standpoint of volume of work done by this process America leads, with Germany second, France third, and England fourth. In scientific research and special development Germany leads all other countries. This is partly due to the fact that the German government has established schools at various places where the art is taught as one of the applied sciences. As one feature of the work being carried on in Germany, it might be mentioned that piping of all sizes and character is now being made by rolling from flat plate and welding by means of the oxyacetylene torch. Piping is also being laid without the use of threads or flange joints. In this way they are enabled to use pipe of about one-half the thickness of our standard pipe, thereby saving greatly in material costs. To show what the German government thinks of this class of work, it is merely necessary to mention that at Cologne, in the Palace of Justice building, recently completed, there are nearly seven miles of piping in which there is not a single threaded joint, all being welded by oxyacetylene.

Static Electricity from Friction. ANON. (*Amer. Mach.*, xli, No. 18, 780.)—The production of static electricity by friction of pulleys and belts has been assigned as the cause of recent dust explosions. Although experiments have not been conducted along this line to show that a dust cloud can be ignited in this manner, a recent experiment at Pittsburgh showed very clearly that sufficient static electricity could be produced by a very small pulley and shaft to ignite gas readily. A milling company in Texas, engaged in grinding cotton-seed cake into meal, states that after experiencing a series of explosions the insulating of a certain grinding machine prevented any repetition of previous occurrences. The fact that explosions have been known to occur at times when the feed of grinding machines was cut off seems to indicate that an unknown factor may be the responsible agent. A series of experiments is being planned under the direction of the U. S. Bureau of Mines in order to determine if static electricity can produce ignition of the dust while in suspension. A preliminary report on the explosibility of grain dusts has already been published by the Bureau.

Cement from Beets. ANON. (*Sci. Amer.*, lxxix, No. 2038, 61.)—A French firm is making an excellent cement from a by-product in the process of making beet-sugar. The scum that forms when the beets are boiled, and which has heretofore been thrown away, consists largely of calcium carbonate and water, and from 70,000 tons of beets treated 4000 tons of calcium carbonate are obtained; to this 1100 tons of clay are added, the resulting product being 3162 tons of excellent cement. The partially-dried scum is mixed with finely-divided clay, amalgamated by beaters, and burned in a rotary kiln.

Ultraviolet Rays for Vulcanizing Rubber. ANON. (*Sci. Amer.*, cxi, No. 25, 503.)—Dissolved rubber can be vulcanized without using heat, and can be kept in a semi-liquid state, although vulcanized, by a new method discovered by a German chemist, Dr. M. Heilbronner. Rubber is dissolved in a light hydrocarbon solvent, in the proportion of fifteen parts of solvent to one of crude rubber. A solution of crystallized sulphur in benzine is then added to the rubber solution and the mixture is subjected to ultraviolet rays from a Cooper-Hewitt mercury vapor lamp in quartz tubes. The rubber in the solution combines with the sulphur, and when the solvent is allowed to evaporate the residue is pure vulcanized (insoluble) rubber. For repairing, the vulcanized solution is used and the solvent is evaporated, giving a sort of "autogenous rubber welding" which fails to disclose the points of contact. When two rubber surfaces are joined by this vulcanized rubber solution a homogeneous mass is formed.

The "Concentrated Filament" Lamp. (*Elect. Rev. and West. Electn.*, lxv, 1013.)—This relates to tungsten filament lamps, which are suitable for projection purposes or for headlights, etc. It is said that a six-volt battery lamp, of 108 watts capacity, will yield over 900,000 candle-power if furnished with a 20-inch parabolic reflector of the silver-plated type. These lamps are said to be used for a great variety of purposes.

PRESS OF
J. B. LIPPINCOTT COMPANY
PHILADELPHIA

JOURNAL

OF

THE FRANKLIN INSTITUTE

DEVOTED TO SCIENCE AND THE MECHANIC ARTS

VOL. CLXXIX JUNE, 1915 No. 6

HIGH TEMPERATURE INVESTIGATION AND A STUDY OF METALLIC CONDUCTION.*

BY

EDWIN F. NORTHRUP, Ph.D.,

Palmer Physical Laboratory, Princeton University.
Member of the Institute.

I. TEMPERATURE A CONDITION OF MATTER.

THE temperature of a body is commonly estimated by touching it and finding if it feels hot, warm, or cold. But if the body glows its temperature is judged by the sense of sight, and the temperature is considered high in proportion to the brightness of the light which the body emits. Again, if a substance, ordinarily observed in its gaseous or liquid form, is seen in its solid form, and is recognized as the same substance, it is then called very cold and is said to be at a low temperature. All sense perceptions inform us that what we call temperature is a word which expresses our recognition of a *condition* under which all matter exists, and common experience shows that this condition varies widely.

Analysis informs us that the condition of matter called temperature is a species of motion, and that this motion is not an organized motion of the mass as a whole, but a disorganized motion of the minute, invisible parts of the body. As the senses give no account of absolute temperature, and only a rough estimate of relative temperatures, a scientific scale of absolute temperature based upon some physical principle, and realizable by observing

---

* Presented at the stated meeting held Wednesday, March 17, 1915.

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

Copyright, 1915, by THE FRANKLIN INSTITUTE.

the variation in some physical property of matter, is required for obtaining any precise quantitative observations. A scale of this character is provided in Lord Kelvin's thermodynamic scale, in which the temperature is defined as a quantity proportional to the mean kinetic energy per molecule of the molecules of a substance. If the molecules of the substance are absolutely at rest, the mean kinetic energy of any molecule is zero and the temperature is zero. A rise of temperature of a uniformly-heated portion of an ideal gas will be in direct proportion to the mean kinetic energy, or to the square of the mean velocity of its molecules. It is shown that when either the volume or pressure of the ideal gas is maintained constant the absolute temperature increases proportionally with an increase in the variable factor. This absolute scale of temperature, which is independent of the nature of any substance, starts with its zero 273° C. below the zero of the centigrade scale. When degrees are expressed in this scale they should be called, and now generally are, degrees Kelvin, in honor of the author of the scale. In temperature investigations we shall assume that a temperature is known precisely to just that extent to which it can be identified with, or can be expressed in terms of, this scale.

In actual observations of high temperature, the point is soon passed where the volume or pressure change in any actual gas can be observed and the true temperature be measured directly on the thermodynamic scale. The limit of the gas thermometer scale is about 1825° K., while it is assumed from various lines of evidence that not less than 4000° K. may be obtained in the laboratory. It follows that any measurement of temperature beyond the limits of the gas thermometer must be based upon the assumption that some property of matter continues to change above 1825° K. by some law of change deduced from observations made below this temperature where comparison with the gas scale is possible. The total radiation and the visible radiation emitted by matter give a valuable means of measuring high temperatures. Certain of the laws by which matter emits radiation rest upon a fairly secure theoretical basis. Since all kinds of matter, under conditions which are generally possible to realize, obey these laws in the same way, one is also justified in referring temperature to the radiation of matter and establishing an absolute scale of temperature upon properties of radiation obeyed alike by all kinds of matter. The connection between the thermodynamic scale and the scales based upon the so-called radiation laws of Stefan-Boltzmann and Wien have been satisfactorily established as high as the melting-point of platinum. However, for these laws to hold, certain conditions (namely, those of black-body radiation) must be fulfilled, and, as these conditions cannot be fulfilled in studying the temperature of the sun, stars, and nebulæ, it is mere speculation to presume that the temperatures of these bodies can be measured. All that may be said regarding the temperature of these bodies is that they emit radiation which corresponds to the kind of radiation a black body would emit if it could be continually raised in temperature beyond anything ever observed and at the same time continue to radiate according to the same laws obeyed in the temperature range where observation is possible. From these considerations we shall assume that quantitative high temperature investigation ends where carbon—the most refractory of all known materials—vaporizes. If vastly higher temperatures are assumed by the astronomers to exist in the sun and stars, we must consider that their assertions refer only to the character of the radiation which they observe, and hence have no direct interest for investigators of terrestrial and realizable temperatures.

If matter with which we can experiment may be submitted to a temperature between 1° or 2° K. and 4000° K., a comprehensive physics of matter will consider and examine its properties as these are presented under all producible temperature conditions. It is a limited aspect of the science of physics to consider that its field is confined to a study of the properties of matter when found in the accidental and narrow range of temperature where life exists. Yet the physics of the past has given us the so-called laws of matter, energy, and electricity where these are considered as concepts of an objective reality that chances to exist between 273° and 373° K.—about 2½ per cent. of the temperature range obtainable. The physics of the present is a broader science, which is more and more recognizing both obligations and immense possibilities for the future. Its obligations are: to extend investigation of the phenomena of matter and the relations of matter to energy and electricity throughout the entire temperature range producible in the laboratory. Its possibilities are: the discovery of new forces, new relations and manifestations of the known forces, and of novel means of utilizing known and yet undiscovered forces to useful ends. By passing to the limits in the study of such quantities as temperature, pressure, current density, magnetic density, rotational velocity, etc., the science of matter, energy, and electricity may hope to acquire the extended vision to which it is entitled, and to view these entities, not in the present restricted and transitory phase of their existence, but over a large extent of the phenomenal history through which they pass in their evolutionary development.

II. VARIATION OF THE PROPERTIES OF MATTER WITH TEMPERATURE.

Most of the properties exhibited by a body change when the conditions are changed under which the body exists. Inertia and weight, however, so far as at present investigated, are not altered by any change in conditions. Temperature is a unique condition in that it affects the properties of matter to a greater extent than any other change of condition to which matter may be subjected. The elements and the compounds of the elements, however, behave quite differently under wide temperature changes. In the case of the elements, though these exhibit widely different properties at different temperatures, when returned to a particular temperature, after having been carried through a wide temperature change, they are found to exhibit, with few unimportant exceptions, the same properties at the same temperature. Thus a non-metallic element, as oxygen, or a metallic element, as gold, exhibits exactly the same characteristic properties at 20° C. whether it has or has not previously been carried to temperatures which extend over the entire producible range. In other words, the chemical elements, in the main, give no evidence at any particular temperature of their previous physical history. Unimportant exceptions to this general statement exist, as shown by the different kinds of crystallization produced in an element by its past physical history. But if the particular temperature is chosen where the element is a fluid, gas, or vapor, then no evidence remains of its past temperature history. Compounds of the elements, on the other hand, show no abiding properties at a particular temperature except inertia and weight, provided they have been carried through temperature changes chosen sufficiently great. All give evidence by dehydration, by decomposition, by polymorphism, by crystallization, by chemical alteration, etc., of their previous temperature history. Thus, if a magnesium silicate, as soapstone, had ever been taken, since its formation, to a temperature of 1000° C., evidence of this would be shown by the flinty hardness always acquired by this material when once subjected to high temperature. Many compounds, chiefly organic, are permanently and entirely altered when the temperature is raised only a few degrees, as when an egg is cooked. Other compounds, notably the oxides of the metals, as the oxides of magnesium, aluminum, etc., are so stable that they give evidence of their temperature history only after being submitted to the greatest extremes of temperature. It thus appears that a full interpretation and understanding of the compounds of the elements, as these are manifested at ordinary temperature, can only become possible by following experimentally the changes produced in the properties of these materials, transient and abiding, as they are submitted to temperatures which cover the entire range of temperature in which they can exist as identifiable materials. Such extended temperature investigations of the compounds of the elements are needed, not only for the better understanding of them at ordinary temperature, but also for the new facts and laws, of probable usefulness, which investigations at unusual temperatures are sure to reveal. Likewise, though to a less extent, the laws of the phenomena of the elements as revealed at ordinary temperature will receive much illumination from investigations of their properties throughout a greatly extended range of temperature, especially when the investigations are extended into the region of high temperature. Investigations made at high temperature are certain to disclose unsuspected properties possessed by the elements which will find important applications in science and the industries. Thus the writer's purely scientific investigation of the resistivity curve of molten tin proved that this material increases linearly with the temperature to at least 1680° C., and he has been able to utilize this heretofore unknown property of tin for all his measurements of high temperature to near 1700° C.

But there is another motive, the same which induces financiers to donate millions to astrophysical laboratories, for investigating the properties of matter over the entire range of temperature to which it may be submitted in the laboratory. This motive is the instinctive craving of the intellect to reproduce as completely and as truly as possible a mind replica of Nature. It is the influence of this motive which has produced the growth of the greater part of our present-day science, physical, chemical, and biological. In the past, however, the natural history, or physics and chemistry of matter, was studied in what may be termed the "life range" of temperature, say −40° to 100° C.—a mere 3½ per cent. of the temperature range in which the properties of matter may now be investigated.

The properties and phases of matter in this very restricted range are, nevertheless, of greater interest generally than at temperatures far removed from the life range, because the interests of human beings are chiefly associated with matter which exhibits the properties which it possesses at ordinary temperature. But by studying the properties of matter at high and low temperatures we shall come to a better understanding of it at the temperature where we come in contact with it and use it. The variety and complexity of the phenomena of matter revealed in a temperature range where there is crystallization and protoplasm and magnetism are far greater than in other temperature interval.

This circumstance, that more data are presented for observation, increases greatly the task of deducing laws and detecting governing principles; that is, mentally abstracting from a variety of phenomena elements which are common to and characteristic of many or all. The surprise is that, with the complexities encountered by the investigators of the past, we inherit as much coördinated truth and generalization as we do. A more searching method of attack is presented to our generation and those to come. This new method consists in the effort to interpret the phenomena manifested by matter in the particular phases which it exhibits in the life range of temperature, by taking the wide view of the properties of matter which is acquired by studying the phenomena which matter presents throughout the entire temperature range. The part is most correctly interpreted when studied in the light of the whole. To attempt an explanation of the physics and chemistry of matter by confining investigation to 3 or 4 per cent. of the temperature range in which matter might be studied is as if an art critic were to try and judge the beauty of Raphael's Sistine Madonna by inspecting one small area of the canvas through a pinhole in a card. The true significance and the beauty of any part selected for inspection may be recognized only when this part is seen from the proper standpoint in its setting and relation to the entire creation. The broad view in science is not less important for the correct understanding of phenomena than in art for the full recognition of beauty.

If the complexity of Nature makes interpretation difficult in the life range of temperature, the technical difficulties, on the other hand, of experimental investigation at low and high temperatures become rapidly greater as investigation is extended in either of these directions.

It is probably due to this circumstance, in part at least, why our knowledge of Nature has been limited hitherto to a very short range of temperature. New inventions and modern methods of research, however, are rapidly removing these limitations. Hence the physicist of the future should have no reason or desire to confine either his investigations or his philosophic inquiries upon the nature and laws of matter, energy, and electricity within the narrow limits held to in the past. The diversity and the number of the problems presented are so vast, however, that the individual investigator desiring intellectual efficiency will select for study the modifications and manifestations of some particular phase or property of matter which abides when a body is carried to great extremes in the temperature range. Thus one might select for study the temperature history of the thermal conductance of one or more varieties of matter, or the vapor pressure, or the magnetic, gravitational, electrical, or molecular forces, or the spectral radiation of certain selected elements.

Of all the properties of matter most deserving investigation, one which is exhibited in all its conditions of temperature, and which has peculiar fascination, is the property possessed by matter of conducting or transporting electricity. We pass then to the particular topic of this paper.

III. THE PROBLEM OF ELECTRICAL CONDUCTION.

Two bodies, as a rod of glass and a piece of silk, ordinarily exhibit no properties at any temperature which we call electrical. Rub them together, then draw them apart. Each is found to be electrified, and in addition the space between them, even though the experiment is performed in a perfect vacuum, has acquired a peculiar condition. The common evidence of this peculiar condition acquired by the space between oppositely electrified bodies is given when any piece of matter which is electrically conducting is held anywhere within the space between the electrified bodies, for it is found to assume an electrification and to exhibit polar properties. The particular point to note is that this peculiar condition of space by which it can electrify bodies held within it is not produced by the presence in the space itself of any material or substance to which can be assigned an objective independent existence. There need be no matter and no electricity in the space. Electricity, which we assume to be an independent entity consisting of extremely minute, discrete elements, called electrons, is located on and associated with the matter. The peculiar condition of the space between electrified bodies is called an electric stress, and is symbolically represented by lines of force which are contractile along their length and repellent normally to their direction. This stress is produced by a mysterious power which resides in the electricity. The electricity itself, however, resides on matter, and only its *influence* goes out of matter into space.

In electromagnetic radiation—as presented in wireless telegraphy and as ever present in the form of radiant heat and light—we observe a propagation of a *state or condition* produced in space by electricity—not a propagation of electricity itself.

Electrical conduction, or, perhaps, more properly stated, the transport of electricity from one point to another in space, is a process which involves (with a possible single exception of pure electronic conduction in high vacua) the transport of the matter itself to which the electricity is attached. The manner of transport of electricity through a metallic element from one point to another point in the metal constitutes the problem of metallic conduction. The manner of transport of electricity through space occupied by matter, gaseous, liquid, or solid, constitutes the larger problem of electrical conduction.

The restraint which a material offers to the passage of electricity from point to point of the substance differs at ordinary temperature with the nature of the material, so much so that substances are divided into two classes, insulators and conductors. If, however, the temperature be raised or lowered, it is found that the ratio of this restraint to the passage of electricity in insulators to the restraint to its passage in conductors changes greatly. When the temperature is exceedingly low, the restraint of insulators to the passage of electricity is practically infinite and the restraint of metallic conductors upon the passage of electricity is practically *nil*. When, on the other hand, the temperature is exceedingly high, the insulators all cease to insulate and the restraint upon the passage of electricity through conductors is greatly enhanced. Thus the ratio, resistance of insulators to resistance of conductors, tends to approach unity with rise of temperature, and we may with probability assume that at 4000° K., the temperature of vaporized carbon, insulators which have become gaseous and conductors which have become vaporized all offer about the same restraint to the passage of electrons from point to point in a space filled with these materials.

The problem of the transport of electricity naturally assumes two aspects: Why does the same element or compound change in conductivity when the temperature changes, and why do different elements or compounds have a different conductivity at a given temperature? In discussing these aspects of the large problem of conduction it should be borne in mind that other conditions than temperature affect electrical conduction. It is modified to a certain extent by many agencies, as magnetism, light, crystallization, and by variations in pressure. But we shall ignore these agencies of minor influence, and assume that the pressure is always atmospheric. Great temperature changes combined with great pressure changes must, however, finally be applied to matter before the physics of matter as found in Nature can be fully considered.

So far as known, the elements especially, and many of the more stable compounds, when brought by temperature to the liquid or vapor phase, are unique in that all marks of physical and chemical past history are erased. Hence when the elements at least are in these phases their electrical conductivity may be studied freed from all those accidental influences (as crystallization, magnetism, mechanical treatment, etc.) which tend to obscure the essential features sought.

In order to bring many of the elements and inorganic compounds into their liquid and vapor phases, means must be provided for producing very elevated temperatures, which for quantitative work must be regulated and measured.

We shall now consider some of the questions involved in the study of metallic conduction at elevated temperatures and under normal pressure. It must be borne in mind, however, that we do not consider that electrical conduction is fully investigated in a broad way and with any pretence to completeness until the manner of transport of electricity through matter is examined experimentally under all the possible conditions of pressure and temperature to which it may be submitted.

IV. DIVERSITY IN THE ELECTRICAL CONDUCTION OF MATTER.

In *Metallurgical and Chemical Engineering* for January, 1915, Dr. Carl Hering has gathered together in five curve sheets a "Comparison of Electrical Resistivities at High Temperatures" of a large number of elements and simple compounds. These curves give a summary of much of the experimental data on resistivities from 273° K. to the highest temperature at which data have been obtained. Curves of a few of the metals plotted from data obtained chiefly by the writer for metals which are molten at high temperature, and from data obtained by others for metals not molten at high temperature, are extended to 1773° K. and above. Curves for simple compounds are carried in several cases to 1373° K., and one curve for alundum (data obtained by the writer) to 1873° K. In "Measurements of Electrical Resistance," by W. A. Price, is given a chart, facing page 14, in which curves are shown for thirty metals and alloys below the temperature of 473° K. and extended down to 73° K. and still lower in a few cases. These data are the summary of the work of Matthiessen and Hockin, first published in 1860 and 1862. Data upon the resistivity of gold, platinum, mercury, and lead at temperatures within two or three degrees of the absolute zero have been obtained recently by Kamerlingh Onnes. Some of Onnes's curves for gold, platinum, and mercury have been reproduced by the writer on page 377 in volume xxv of the *Transactions of the American Electrochemical Society*.

In examining these various curves, even though the attention is confined to the curves of the pure metals, one is struck with the great diversity in resistivities at any given temperature. It appears that in no single case, also, does a metal fail to show inflections in its curve if it has been studied over a long range of temperature, and that whenever the metal changes state, in passing from solid to molten, its curve changes abruptly. It at once becomes apparent that it would be impossible to embody the facts of metallic conduction as revealed in these curves, and still less the facts of the conduction of compounds, in general equations, provided these equations are to apply over any considerable range of temperature. Nevertheless, theories of metallic conduction have been proposed and equations have been deduced that rest upon a theory which seems to fit the facts for change in metallic resistance with temperature, provided the temperature range considered is sufficiently restricted. But no theory has yet been proposed, capable of taking mathematical form, that can account for the facts of metallic conduction over any extended temperature range, particularly if the range takes the metal through a change of state, or, indeed, through any change in its molecular aggregation. It may be true that a guiding and coördinating principle may be contrived of very hazy outline, but no *law* of resistance change or explanation of absolute resistivity under a given condition, which has any pretence to precision, has so far been announced. We shall, however, consider the most generally accepted theory of metallic conduction and then propose a hypothesis of our own. Before doing so, however, it will be convenient to consider first the principles of the methods which at present seem well adapted to the study of electrical conduction at temperatures exceeding 1273° K. and to offer some comments on the facts of conduction which have been ascertained so far.

V. THE PRODUCTION OF HIGH TEMPERATURE FOR THE EXPERIMENTAL STUDY OF ELECTRICAL CONDUCTION.

All bodies tend to come into both temperature and chemical equilibrium with their surroundings. If high temperature wipes out the past physical history of bodies, it tends, on the other hand, to establish new chemical equilibria. Materials in general, and pure metals in particular, generally suffer large alterations in resistivity from very slight chemical reactions or from the addition of small amounts of foreign materials. It is to be noted, also, that when materials are heated to a high temperature under low pressure they evaporate and finally boil, the more readily as the pressure is made lower. The above properties of matter require careful consideration in planning methods for the study of electrical conduction at high temperature.

For accurate quantitative work in the measurement of electrical resistivity at high temperature it is necessary to devise a means of producing, by gradual gradations, not only a high temperature but a temperature which can be made uniform throughout a considerable volume. Furthermore, it is convenient and very desirable that the material to be studied should be under a pressure at least not below the normal, and, for the solution of certain problems, it should be possible to submit the material to be measured to pressures which greatly exceed the normal. If the pressure is greater than zero it becomes necessary to immerse the material under study in some other substance, gaseous or fluid, and at the same time meet the condition that the temperature equilibrium between the material under study and the substance in which it is immersed shall remain unaltered throughout the entire temperature range in which measurements are to be made. If the material being studied becomes fluid or gaseous at any temperature employed, then a container must be provided. The material of this container must likewise remain at all temperatures used in chemical equilibrium with the material studied. Furthermore, since every compound and certain elements are porous at high temperature (to the extent that the substance, if gaseous, in which they may be immersed is physically absorbed into their pores), precautions must be adopted that the true conductance of the material is being measured and not the conductance of the material plus the conductance of the gas, vapor, or fluid held mechanically in the interstices of the specimen. Thus, if the conductivity of Al_2O_3 powder is measured at 1550° C. when immersed in a $CO + N$ atmosphere, too large a value by some 20 per cent. would be obtained for its conductivity, because the conductivity of the Al_2O_3 and the gas in its interstices would be measured together in parallel.[1]

These are hard requirements for the study of electrical conductivity at high temperature, and the difficulties encountered in meeting them increase at a greatly accelerated rate as the temperature is made to exceed 1000° C.

The production of a uniform and controllable high temperature throughout a volume of considerable dimensions has been accomplished by the writer by the construction of an electric furnace which employs a heater of pure Acheson graphite. By heating in cascade the highest temperatures are readily produced. In applying this principle an outside graphite heater is encased in refractory materials and is heated to a temperature which these refractories will endure. Another inside and smaller graphite heater is suspended from above by massive graphite electrodes. When the outside heater has been raised to 1500° or 1600° C. the inside heater is further heated electrically to any temperature desired up to the temperature where graphite vaporizes under normal atmospheric pressure.[2] If means were to be provided, as they might be, for greatly increasing the pressure, it is probable that still higher temperatures could be produced. When avoiding the use of a vacuum or low pressures, for the reasons stated, it is necessary to determine what material, if any, gas, liquid, or solid, can be used in the furnace, which will remain in chemical equilibrium both with the furnace walls and with the specimen, the resistivity of which is to be measured. The determination of this matter alone involves much research. Certain it is, however, that the walls of the furnace will be in perfect chemical equilibrium with the gaseous products which remain in the furnace after a certain very small portion of the graphite has interacted with the original air or gas in the furnace (provided new quantities of gas or air are not admitted—a matter easily cared for). When no gas other than air enters the furnace, the product which remains after all interaction between air and graphite has ceased is, presumably, $CO + N$, though at very high temperatures finely-subdivided particles of pure carbon are also present. It is experimentally found that many, though by no means all, metals give every evidence of being chemically inert in this mixture of gases. Several metals, on the other hand, are chemically and physically modified at a high temperature when immersed in this gas mixture. Thus molybdenum and tungsten become brittle and the melting-point of platinum is much lowered. Copper, gold, and tin, on the other hand, give no evidence of any chemical interaction with $CO + N$ even at a temperature as high as 1500° C. or higher. The writer has not worked with other gases, as nitrogen, hydrogen, etc., and is unacquainted with the phenomena which would be manifested. It would be an excellent line of investigation to determine the conditions of chemical equilibria and chemical interaction of the metallic elements, also the solid non-metallic elements, with the gaseous elements and the gaseous compounds at high temperature. How, for example, would molybdenum behave at 1500° C. in a vapor of carbon tetrachloride?

---

[1] Consult "Methods, Data and New Apparatus for Measuring Electrical Conductivity Above 1500° C. of Vapors at Normal Pressure," by Edwin F. Northrup, Journal of The Franklin Institute, March, 1915, p. 352.

---

[2] A furnace and cascade attachment has been described by the writer in *Metallurgical and Chemical Engineering*, January, 1914, and May, 1914.

Experience has shown that a furnace of small size cannot with best advantage be furnished with a heater unit of pure graphite because the consumption of a small amount of the graphite has a large percentage influence in the destruction of the heater unit, and, furthermore, graphite in small masses is not strong mechanically. For this reason the small model furnace, designed by the writer, employs a highly refractory metal as a heating element. The unit, of refractory material in which this metal is held, is encased on the outside and lined on the inside with graphite. The oxidation temperature of the graphite is lower than that of the metal, and before the metal has opportunity to oxidize a small portion of the graphite lining oxidizes, filling the furnace with a $CO + N$ atmosphere which permanently protects the metal from oxidation.

The General Electric Company has developed an excellent molybdenum wound furnace in which the molybdenum winding is protected from oxidation by being maintained in an atmosphere of hydrogen. This type of furnace, however, is unsuited for the heat treatment of materials which absorb or are in any way affected by hydrogen, and it could not, therefore, for this and other reasons, be employed with advantage in determining the resistivity curves of several of the metals.

To obtain the uniform temperature required throughout a considerable volume, the writer has used the principle in both his large and small types of furnaces of causing the heating current to pass lengthwise many times from one end to the other of a cylindrical-heater unit instead of going circularly around it, or passing but once, at very low voltage, through a cylindrical tube. This disposition of the heating current gives almost perfect black-body conditions throughout a considerable portion of the furnace chamber.

The measurements of the high temperatures employed is not less important for quantitative work than their production and control. The platinum *vs.* platinum plus ten per cent. rhodium thermocouple generally opens circuits and fails to operate in a $CO + N$ atmosphere at a temperature in the neighborhood of

1500° C. It is troublesome to use and cannot be considered reliable, without frequent recalibration, at these high temperatures. Optical or radiation pyrometers, furthermore, are not well suited to precision work in the determination of the resistivities of the metals, chiefly because of the difficulties and labor of sighting directly upon the portion of the molten metal which is being measured, and also because observations are often required below a temperature where these instruments are useful or accurate. It was found desirable, therefore, to devise a new type of pyrometer, operating upon a new principle, which might be submitted to exactly the same temperature as the metal being measured and which would operate with perfect reliability as high as 1600° or 1700° C. Such a pyrometer was easily devised after the electrical and other properties of molten tin and molten lead had been studied. These two metals, tin in particular, melt at a low temperature and only evaporate appreciably or boil at a very high temperature, and, what is very essential in precision work, they increase in resistance when molten in a perfectly regular way to a very high temperature. The linear increase in tin with increase in temperature has been investigated by the writer and found to hold to at least 1680° C., and it is probable that this linear increase continues to near the boiling-point of tin, which exceeds 2000° C. Pure lead also increases linearly from its melting-point to 1600° C. This property of tin is employed in a very simple manner in the construction of a direct reading and direct insertion pyrometer for use up to 1700° C. or higher. As the increase in the resistance of tin is linear, it is possible and easy to so choose the resistances of the Kelvin double bridge used in measuring the resistance of the pyrometer that the indications of the bridge upon a uniformly-spaced scale read directly in degrees centigrade. At these high temperatures, however, parasitic and irregular electromotive forces always develop within the pyrometer, but their disturbing influence may be avoided, however, by using alternating current for the measuring current. This in turn requires the employment of a galvanometer in connection with the Kelvin double bridge which responds to alternating current only and which is not in the least affected by any direct electromotive force in its circuit.

Both pyrometers and galvanometers of the above types, which meet perfectly the required conditions, have been constructed, and are being much used in measurements made by the writer and Mr. R. G. Sherwood, working under the writer's guidance. The problem, therefore, of measuring the temperature to at least 1700° C. is now fully and very satisfactorily solved.

More detailed descriptions of this method of measuring and reading temperatures will be given in later publications.

When the temperatures produced (as by means of the cascade attachment) exceed 1700° C., no other means for their accurate determination through a series of ascending values are now available than the well-known optical or radiation methods. It should be noted, however, that in applying these methods large inaccuracies may occur, due to an unknown absorption of light or radiant heat by fumes or absorbent gases in the furnace chamber, or by windows placed between the high-temperature zone and the instrument. When a very high temperature is produced in a vacuum-type furnace, the radiation must pass, not only through a window, the transparency of which is likely to become decreased by deposits on its under side, but also through absorbing vapors, which are much more prone to form at low pressure than they are at atmospheric pressure. It is therefore apparent that, when the highest temperatures are obtained in the cascade attachment at atmospheric pressure and with an uncovered opening through which observations into a region at black-body temperature may be made, optical and radiation methods of measuring temperature are relatively easy and little likely to be in error.

VI. CHARACTERISTIC FACTS OF METALLIC CONDUCTION NOW KNOWN.

The chemical elements, when studied by themselves under certain imposed conditions, show their characteristic phenomena more unmistakably than when two or more of the elements, physically or chemically combined, are studied. In seeking features, therefore, which are characteristic of a group of phenomena, as the phenomena of electrical conduction exhibited under widely-varied conditions of temperature, investigations should begin with the pure chemical elements. It thus becomes far easier to ascertain and to mentally abstract, for purposes of classification, for seeking analogies, or for tracing curves, those phenomena which are essential and characteristic than when complexities are added by studying the elements in physical or chemical groups. For this reason an investigation of metallic conduction should begin with a study of the purest metallic elements obtainable, and the changes in the phenomena of the conduction of these elements should be traced as the one condition of temperature only is gradually varied through the widest range experimentally realizable. This searching procedure has recently been followed with much success. From the work so far done the metallic elements may be grouped in respect to their property of electrical conduction as follows:

1. Elements which either melt at so high a temperature or enter so readily at high temperature into chemical combinations with any surrounding substance that their resistivity curves have not been traced over a temperature range in which they pass through a change of state. To this group belong such metals as iron, nickel, cobalt, tungsten, molybdenum, tantalum, platinum, iridium, rhodium, etc.

2. Elements which upon becoming molten about double in resistance as they pass from the completely solid to the completely liquid state and thereafter increase in resistance with rise in temperature in a strictly linear way to near their vaporization temperature or to the highest temperature at which they have been examined. To this group belong aluminum, copper, tin, gold, silver, and lead.

3. Elements which upon liquefying suddenly increase in resistance and thereafter possess a positive temperature coefficient which is only approximately constant. To this group belong mercury, sodium, and potassium.

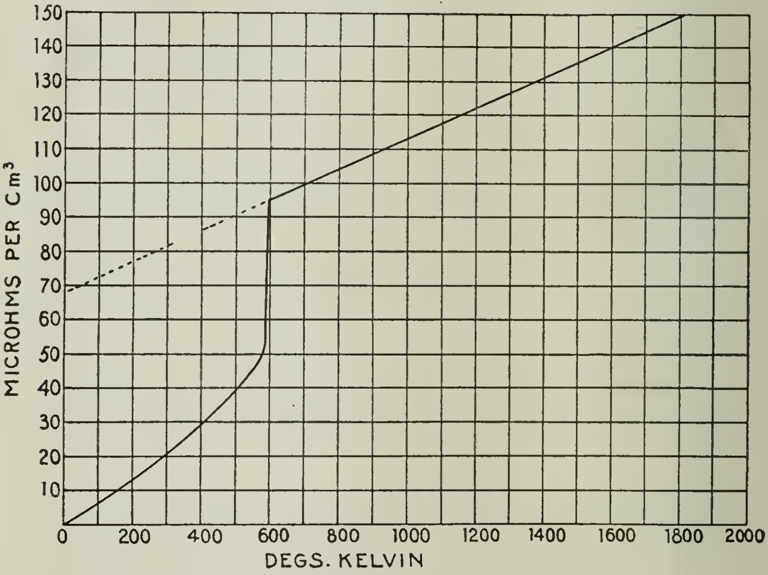
4. Elements which upon liquefying suddenly increase in resistance, about doubling, and thereafter possess over a considerable range of temperature a negative coefficient which gradually changes to positive before vaporization is reached. Zinc and cadmium are the only known representatives of this group.

5. Elements which upon liquefying more or less suddenly decrease in resistance and thereafter steadily increase. Antimony and bismuth are the only two known representatives in this group. Antimony was found by the writer and V. A. Suydam to exhibit an increasing rate of increase in resistance in the molten state, but the writer now believes this result needs reëxamination, as errors may have crept into the measurements made at the highest temperatures. Such errors could have occurred from the formation, by the container then used, of a gas which could change in an

unknown way the cross-section of the column of metal then being measured. The characteristics of bismuth, on the other hand, are known with certainty. This metal decreases in resistance with great abruptness upon becoming molten, the resistance becoming less than half. It thereafter has a strictly linear increase in resistance, certainly to 775° C. and probably to near its vaporization temperature.

The metals belonging to group 2 may be considered as having the normal characteristics of the electrical conduction of pure metallic elements. From the work done upon these metals at both low and high temperature we are able to give with considerable precision the resistivity curve of a typical metal, as lead, traced from very near the absolute zero to about 1873° K. The curve for lead is shown in Fig. 1.

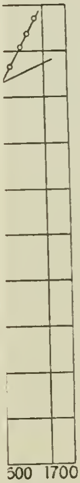
FIG. 1.



Lead, typical resistivity curve.

It is to be noted that the resistivity of lead increases steadily from zero at 0° K., with a slight convexity in the curve toward the temperature axis, until the metal melts at 600° K., at which temperature the resistivity almost exactly doubles with abruptness. After fusion is complete the resistivity continues to increase

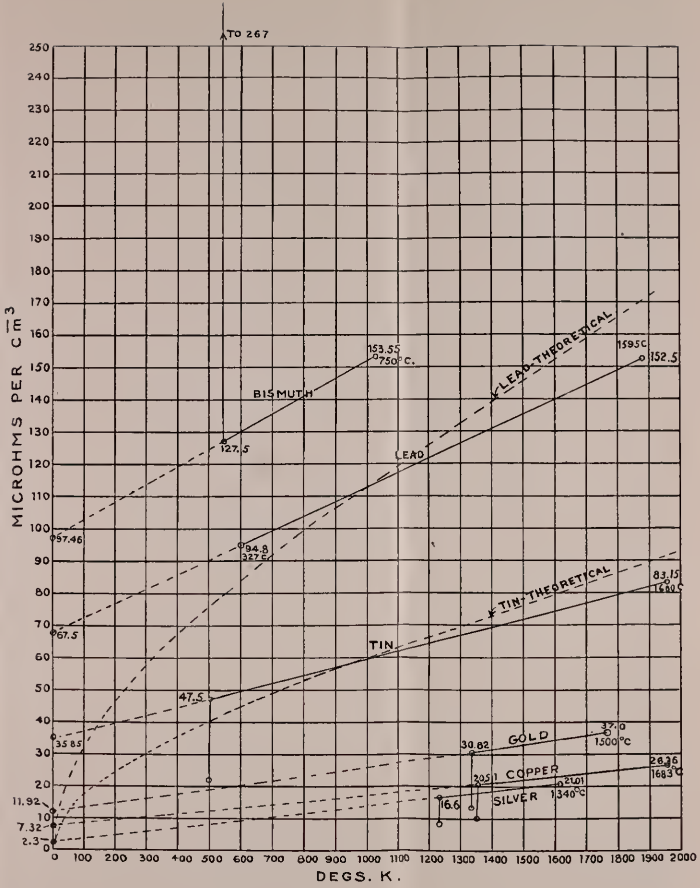
boils.
ure to
of the
ts the
it cuts
o.
nd his
to the
solute
of the



ntally-
tion of

molten
curves,
te zero
to this
e same
at the
ndicate
metals

Fig. 2.

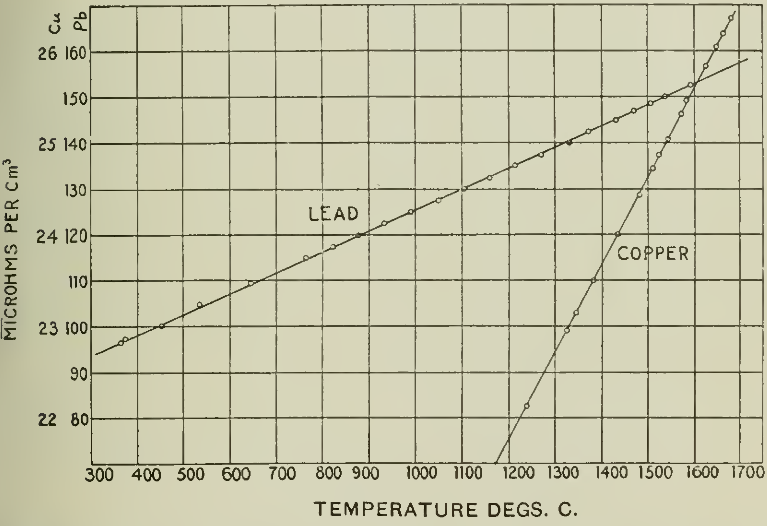


TO 267
MICROHMS PER $C\overline{m}^3$
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
11.92
7.32
2.3
153.55
750°C.
BISMUTH
127.5
LEAD-THEORETICAL
1595C
152.5
LEAD
97.46
94.8
327 C
TIN-THEORETICAL
83.15
1600 C
67.5
TIN
47.5
35.85
GOLD
30.82
37.0
1500°C
COPPER
20.51
26.36
1683°C
SILVER
16.6
21.01
1340°C
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
DEGS. K.

exactly proportional to the temperature until the metal boils. This increase in resistivity (and this is an important feature to note) is not sufficiently fast, however, so that a projection of the curve for the molten metal toward lower temperature cuts the temperature axis near the absolute zero. On the contrary, it cuts the temperature axis at about 1480° below the absolute zero.

In Fig. 2 we give, from data obtained by the writer and his assistants, curves for Bi, Pb, Sn, Au, Cu, and Ag, all plotted to the same scale, of the resistivities of these metals *vs.* the absolute temperature in their molten state. In Fig. 3 a portion of the curves for lead and copper are repeated with the experimentally-obtained points shown upon the curves to give an indication of the precision of the observations.

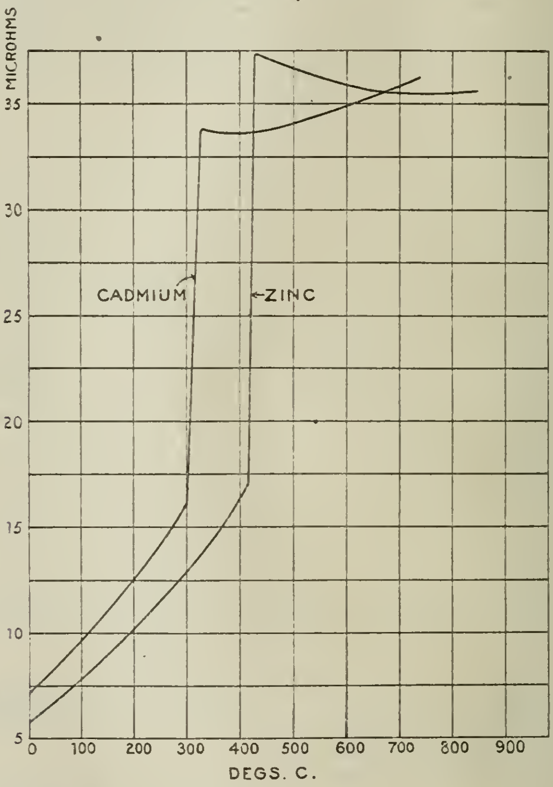
FIG. 3.



These six metals increase in resistivity when in the molten state in a strictly linear manner. The extensions to the curves, shown in dotted lines, give the resistivities at the absolute zero which these metals would have if they continued molten to this temperature and continued to change in resistivity in the same way down to absolute zero. The vertical lines drawn at the temperatures (in degrees K.) at which the metals melt indicate by their free extremities the resistivities acquired by the metals when they pass from the liquid into the solid state.

In Fig. 4 are given curves for zinc and cadmium in a temperature range where these metals, the only two representatives among the pure metals of group 4, are both solid and molten. The strongly-marked negative coefficient of zinc in the molten state is quite remarkable and forms a stumbling-block in any theory of metallic conduction thus far proposed. As the resistance of brass also decreases with increase in temperature so soon as the brass becomes molten, the negative temperature coefficient of zinc appears to manifest itself even when alloyed with copper, which has a constant positive coefficient when in the molten state. As another example of the persistence of a property of an element when alloyed with another element may be mentioned the case of an alloy of tin and bismuth in atomic proportions. Both these metals have a positive and constant coefficient in the molten state,

FIG. 4.



and so has their alloy. The bismuth, however, which decreases in resistance, in passing from solid to molten, impresses this characteristic on its alloy with tin, though the decrease in the alloy is less in magnitude than in the bismuth itself. The curve for this alloy has been accurately obtained experimentally, by the writer and R. G. Sherwood, to a temperature of about 1100° C.

Some prominent facts of metallic conduction over a wide range of temperature are listed below:

a. All metallic elements exhibit at ordinary temperature a conductivity which is about a million times as great as the conductivity of electrolytes.

b. The general tendency of pure metals, but not of alloys, is to reach zero resistance at zero degrees Kelvin and to steadily increase in resistance with rise in temperature, except when the metal passes through a change of state or when from any cause the molecular aggregation changes (as when nickel or iron loses its magnetism from increase in temperature).

c. When a change of state occurs this change is, without exception, accompanied by a change in resistance, which is more or less sudden. If the change in state occurs very abruptly the change in resistance is also abrupt, as shown in the case of bismuth. If the change of state is somewhat gradual the change in resistance is less abrupt, as is shown when aluminum melts.

d. The general tendency is for the resistance to become linear when the metal becomes molten. So far as studied, this seems to be the tendency also with alloys.

e. The increase in resistance when the metal is molten is never so rapid that the curve when projected toward lower temperature ever cuts the temperature axis near zero degrees K., but always far below it.

f. An increase in metallic resistance is always accompanied by a decrease in density, and when, as happens in the case of antimony and bismuth, the density increases the resistance decreases.

g. The ratio, coefficient of resistance of molten metals which change linearly in the molten state to the coefficient of volume expansion in the molten state, is quite approximately the same for those metals which have been examined in this particular. The writer has directed attention to this feature in "Electrical Conduction at High Temperature and its Measurement," page 388, *Transactions of the American Electrochemical Society,* vol. xxv, 1914. This ratio varies from about 3.48 to 5.34 as there given. More accurate measurements made recently have shown that the differences in these ratios are less than this.

h. When metals crystallize, when they are powdered and probably when the powders of different metals are mixed together, and when metals are alloyed together, the resistivity is always increased. While there seem to be several exceptions, in a very general way metals of high atomic weight have high resistivity.

When the pure metals had been examined in the solid state only, and it was found that their projected resistivity curves all pointed toward the zero of absolute temperature, the attempt was made to explain these facts of metallic conduction by an application of the new electron theory. A formula, based upon a theory of free electrons within the metal, was proposed. The formula expresses the assumed infinite conductivity of the pure metals at zero degrees K. and its continual decrease without curve inflections with increase in temperature. As this free electron theory of metallic conduction has enjoyed the support of eminent authority and is given in recent literature as the most probable theory, we have a circumstance which justifies us in presenting here its essential aspects and inquiring if it is sufficient to cover the facts, or if a better hypothesis may be offered. We proceed to this presentation and endeavor.

VII. METALLIC CONDUCTION: THEORY OF CONDUCTION BY FREE ELECTRONS.

The hypothesis adopted to account for metallic conduction is derived from the kinetic theory of gases. The assumption that the mechanism of metallic conduction consists of free electrons was introduced into electronic theory by Drude and J. J. Thomson.

We may picture the views of these authors as follows: Conceive the molecules of a solid metal as not completely filling the space of the volume which contains them. The unoccupied space existing among the molecules would result from the geometrical reason that closely-packed bodies which approach a spherical form occupy only a portion of the volume in which they are contained, or the unoccupied space might result from the fact that the average separation between centres of adjacent molecules is greater than the average diameter of the molecules. The molecules themselves are conceived as capable of being carriers of electrons, and that any molecule is electrically neutral when the sum of the negative charges of the electrons associated with it is equal to the positive charge held by the molecule. The theory assumes, however, that not all the electrons required to make the molecules neutral remain attached to the molecules and thus partake in the motions of the molecules which result from heat agitation. On the contrary, it is assumed that a certain portion of all the electrons in the unit of volume become detached from the molecules, and that they move about as individual units, pursuing zigzag paths among the molecules in the unoccupied space. Those electrons which remain attached to the molecules are called bound electrons, and those which become detached from the molecules of the metal are called free electrons. It is assumed, in short, that the movements of the free electrons are in all respects like the movements assigned to the molecules of a gas in the kinetic theory of gases. They are supposed to move with all possible velocities, but, on account of their great number, to possess for any given temperature a certain definite average velocity which can be calculated from considerations based upon the laws of probability. These free electrons are assumed to be the sole carriers of electricity when current flows in a metal.

By a well-known theorem in the kinetic theory of gases, the mean kinetic energy of a large number of particles of any kind or mass is the same for a given absolute temperature. This holds, whatever the nature or whatever the size of the individual particles. Thus in a mixture of two kinds of molecules the average kinetic energy of each kind is the same. Hence, as the mass of an electron is very small as compared with a molecule of gas, the average velocity of the free electrons, to possess the same average kinetic energy as an equal number of gas molecules at the same temperature, is far greater than the average velocity of the molecules. The electrons, however, are only carried, on the average, comparatively short distances before they encounter other electrons or molecules of the metal. Upon the basis of the above-assumed mechanism, J. J. Thomson arrives at an expression for the electrical conductivity of a metal as follows:

The expression for Ohm's law is that the current is equal to the electromotive force times the conductivity of the medium (conductance through a unit length of a unit cross-section of the material) or,

$$i = kE \quad \text{(1)}$$

where k is the conductivity and E is the electric force per unit length of the conductor.

Assume that in the unit of volume of the metal there are n free electrons. Before an electromotive force is applied to the metal these n electrons will be moving, upon the average, as many in one direction as in another. Now let an electromotive force E per unit length of the conductor be applied. Call e the charge on an electron (all electrons have the same charge). Each electron will now be subjected to a force which will tend to give it a component of motion in a direction opposite to the direction of the force (opposite to and not with the force, because the charge on the electron is negative). Ee is the magnitude of the force on one electron. If the electron is free it will be accelerated in the opposite direction to the force and the acceleration will be

$$m\frac{d^2s}{dt^2} = Ee \quad \text{(2)}$$

where m is the mass of the electron, s is the distance which the electron moves, and t is the time. The velocity acquired by the electron at the end of a time t is

$$v = \frac{ds}{dt} = \frac{Eet}{m} \quad \text{(3)}$$

No constant from the integration appears in the right member of equation (3) because it is assumed that the electron starts from rest and begins to move when the time is zero, as it is supposed to lose at each encounter any velocity given to it by the electric force. Let T be the average time that elapses between two encounters of a free electron. Then the average velocity acquired by the electron between two encounters is

$$V = \frac{1}{2}\frac{EeT}{m} \quad \text{(4)}$$

The quantity of electricity transported in the unit of time is the electric current, and this will equal the number of electrons which cross unit of section of the conductor times the charge e on each electron. The number of electrons to cross a unit section of the conductor in unit time will be equal to n, the number per unit volume which are free times the average velocity with which they move. Hence,

$$i = neV = \frac{Tne^2}{2m} E \quad \text{.......................} (5)$$

Since E is the electromotive force, $\frac{Tne^2}{2m}$ is the conductivity.

If L is the average distance which an electron traverses between two encounters (the so-called mean free path of an electron), $T = \frac{L}{V}$, and we derive for the conductivity

$$\sigma = \frac{Lne^2}{2Vm} \quad \text{..........................} (6)$$

According to the dynamical theory of gases, the kinetic energy of a particle or molecule is proportional to its absolute temperature, or,

$$\tfrac{1}{2} mV^2 = K\theta \quad \text{......................} (7)$$

where θ is the absolute temperature of the gas, m the mass of a molecule, V the mean velocity of a molecule, and K a universal constant; that is, a constant which is independent of the nature of the material considered. From equation (7) $V = \sqrt{\frac{2K\theta}{m}}$, and equation (6) becomes

$$\sigma = \frac{Lne^2}{2\sqrt{2Km\theta}} \quad \text{..........................} (8)$$

also

$$\sigma = \frac{LnVe^2}{4K\theta} \quad \text{..........................} (9)$$

or

$$\frac{1}{\sigma} = \rho = \frac{4K\theta}{LnVe^2} \quad \text{........................} (10)$$

where ρ is the resistivity.

Equations (8) and (9) are the expressions for the conductivity of a pure metal ordinarily derived by making the hypothesis that a certain number n per unit volume of the electrons are free and have motions like gas molecules.

Of the quantities which occur in these equations we are completely ignorant, from any experimental evidence, of the mean free path L and the number of free electrons n. The mass m of an electron, the charge e on an electron, and the universal constant K are known from experimental data, and V may be calculated. Thus,

$m = 8.8 \times 10^{-28}$ gm. when the velocity is slow.

$e = 4.7 \times 10^{-10}$ electrostatic units.

$K = 1.8 \times 10^{-16}$

$V = 1.16 \times 10^{-7}$ cm/sec. at zero degrees C.

Referring to the expression for the conductivity given in equation (8), it is to be noted that the conductivity varies inversely as the square root of the absolute temperature. Experiment shows, however, that pure metals, when in the solid state, decrease in conductivity more nearly directly as the absolute temperature increases. Hence, to bring the theory into agreement with the facts, use is made of expression (9) for the conductivity, and the further assumption is made that the product LnV is constant. Since a metal has only a small expansion with increase in temperature, we should expect that L, the mean free path, would remain nearly constant, and, as the average velocity of the electrons must certainly increase when the temperature increases, there is a necessity for the assumption that n, the number of free electrons, *decreases* when the temperature *increases*. This quite arbitrary and unlikely assumption, unsupported by any experimental evidence, would alone appear sufficient to lead to a rejection of the theory. It probably would have done so if it were not for the further support which the theory appears to acquire when it is applied to a calculation of the ratio of the thermal to the electrical conductivity, and to the explanation which it seems to give of thermo-electromotive force.

By a process of reasoning based upon the theory, but which we cannot take space to give here, an expression is reached for the ratio of the thermal to the electrical conductivity, which appears to accord, in a limited range of temperature, fairly well with the facts. The expression is:

$$\frac{k}{\sigma} = \frac{4}{3}\left(\frac{K}{e}\right)^2 \theta \qquad (11)$$

For 18° C. this expression gives:

$$\frac{k}{\sigma} = 7.15 \times 10^{-11} \qquad (12)$$

This result means that the ratio of the thermal to the electrical conductivity is proportional to the absolute temperature, and for any given temperature is a universal constant; that is, the same constant for any kind of material. The conclusion expressed in equation (11) is known under the name of the "Wiedemann-Franz Law," and for a temperature range between 0° C. and 100° C. agrees remarkably well with the experimental facts in the case of the pure metals.[3] Whether or no this law continues to hold when the metal passes through a change of state, is not known, so far as the writer is informed. A rough experiment, made by the writer on the thermal conductivity of tin just before and just after fusion, gave somewhat ambiguous results, but seemed to indicate that the law does not hold. This experiment should be repeated with care in the case of several metals having low fusion points.

The writer would like to give a further explanation and defence of the free electron theory of metallic conduction, but lack of space compels him to proceed at once to his reasons for rejecting it, and to the presentation of a hypothesis which appears to him to give a more natural and better account of the experimental facts.

The writer rejects the free electron theory of metallic conduction for the following reasons:

1. It is highly artificial. Since a mass of any metal is very nearly electrically neutral, if the space in the interstices of its atomic groups is occupied with a large number of negative electrons, then these atomic groups must be electrically strongly positive. A condition must therefore exist which is unlike anything ever observed, for we must suppose that many electrons continue to remain free in space while being acted upon by the attractive forces of positively-electrified atomic groups. If it be supposed that the electrons are being continually knocked off by the violent collisions resulting from the heat agitation of the atoms and molecules, then there should be many more free electrons at high than at low temperature. But the facts are, that when the temperature approaches absolute zero the con-

---

[3] See Table V, p. 68, "Modern Electrical Theory," by Norman Robert Campbell.

ductivity of a pure metal approaches infinity, and this can only be accounted for, upon the theory, by assuming an increase in the production of free electrons at very low temperature. What are the forces at 2° K., where the atomic groups are almost completely quiescent, which would maintain negative electrons free in space among the interstices of highly-charged positive atomic groups?

2. The theory of free electrons offers no explanation of the sudden change in resistance which occurs with a change of state of the metal. The sudden rise or sudden decrease in resistivity which occurs when a metal melts could be explained only on the theory of free electrons by supposing that when a metal very slightly expands upon liquefying, there is an enormous and sudden decrease in the number of free electrons in the metal, and if the metal very slightly contracts upon liquefying, there is an equally and sudden increase in the number of free electrons. Such assumptions, for which there is not the slightest evidence, would only be made to force the theory to agree with the facts. No formulæ which rest upon a theory of free electrons can be written which even approximately express the relation between resistivity and temperature over a range of temperature which includes changes of state in the metal, unless additional hypotheses are introduced which are more artificial than the original hypothesis.

3. The theory of free electrons can only pretend to account for a *change* in resistance of a given metal with temperature. It has no explanation to give for the different resistivities of *different* metals when at the *same* temperature.

4. What becomes of the free electrons when a metal is vaporized and the vapor is expanded? Do they reënter the atoms when these become far separated by expansion but leave them again when the vapor condenses, and then continue to increase in number in the interstices of the atomic groups, becoming most numerous when the metal is solid and its atomic groups have become quiescent at a near approach to absolute zero? There is no direct evidence that free electrons exist anywhere, except it be in a very high vacuum, and even here (as in the stream of free electrons observed in the Coolidge X-ray tube) it is hard to conceive of the existence of a volume distribution of electricity of one sign only.

VIII. METALLIC CONDUCTION: ELECTRIC TRANSPORT HYPOTHESIS.

In seeking a hypothesis respecting the nature of the process of metallic conduction, it appears to the writer profitable to avoid introducing any assumptions of the existence of a mechanism, or of a condition which cannot be directly observed. It seems desirable rather, to attempt an explanation of the process of electrical conduction, where the process cannot be directly observed, by assuming it to be similar in character to a species of electrical conduction which may be directly observed. Thus suppose two insulated metal bodies are located a short distance apart, and that they are joined, one to the positive and one to the negative coating, of a charged Leyden jar. If now a small insulated conducting body continually makes excursions between the two metal bodies, it will at each double excursion transport a certain quantity of negative electricity from the negatively-charged coating to the positively-charged coating, until the Leyden jar is wholly discharged. In this process of electric transport we have a species of electrical conduction which may be directly observed and its laws fully determined. The existence also, and the magnitude of the ultimate unit of negative electricity, may be directly observed and measured. If, therefore, we can show how the process of the passage of electricity through a metal is a process of the same general character as the observable processes of electric transport and that it is the negative electrons which are transported, we have explained metallic conduction without introducing artificial mechanisms or conditions, so far as any explanation is possible.

Now any hypothesis, theory, or explanation of metallic conduction to be adequate must give a reasonable account of the experimental facts—not over one or two per cent. of the temperature range in which experimental facts have been obtained, but over the entire temperature range in which such facts are known. This range certainly extends, at the present time, from about 2° K. to about 2000° K.—a range in which many metals pass from solid to liquid and finally vaporize. An adequate hypothesis then must at least coördinate and give a reasonable, if not a numerical, account of the fundamental facts of conduction as stated in Section VI above.

If we select a metal which exhibits a normal behavior, as lead, the curve of which is given on page 638, Fig. 1, we may express its change in resistivity with temperature by means of an empirical expression of the following form:

$$\rho_\theta = \Big|_{0}^{\theta_s} \rho_0(1 + \alpha\theta + \beta\theta^2) \Big|_{\theta_e}^{\theta_b} K + \delta\,(\theta_b - \theta_e) \ldots\ldots\ldots\ldots (13)$$

Here $\Big|_{0}^{\theta_s}$ means that only the symbols which precede the second vertical line apply when the temperature lies in the limits 0 and θ_s degrees Kelvin, where θ_s is the highest temperature at which the metal is solid, and the symbol $\Big|_{\theta_e}^{\theta_b}$ means that only the symbols which follow the second vertical line apply where θ_e is the temperature in degrees Kelvin at which the metal has become wholly liquid, and θ_b the temperature at which it boils. α and β are coefficients which must be experimentally obtained for the metal in the solid state. K is the resistivity of the metal just after fusion at temperature θ_e, and δ is a constant which determines the rate at which the resistivity increases when the metal is in the liquid state.

In seeking a theoretical basis for the above purely empirical equation, we shall make use of certain fundamental, but not artificial, assumptions, but before doing so it will be well to consider certain relations between current and energy which are independent of our assumptions, and of the particular form of any theory of metallic conduction.

Current and Energy Relations.

In deducing these relations we accept as proved by experiment that there exists an indivisible and ultimate quantity of electricity called the electron, and that it is equal approximately to 1.57×10^{-20} electromagnetic units. With the above understood, consider the work done when by any process whatever electrons pass from a point P_1 to a point P_2. If a unit charge of negative electricity moves by any path whatever from the point P_1 at potential V to point P_2 at potential 0 the work done by the electric forces will be

$$W_1 = 1 \times (V - 0) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (14)$$

If E units move in this manner, the work done will be

$$W_2 = EV \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (15)$$

Let us analyze the character or nature of this work. Suppose the negative electricity which moves from P_1 to P_2 is distributed over the surface of a very small sphere, and that in its passage from one point to another the sphere moves in a perfect vacuum; then the work done will take the form of some type of electromagnetic radiation which probably will manifest greatest intensity when the velocity of the charged sphere is reduced quickly to zero upon arriving at the point P_2. If, on the other hand, the charged sphere makes its journey from P_1 to P_2 against a frictional restraint, or if it passes through the midst of a multitude of perfectly insulating molecules of matter with which it makes frequent encounters, it will, in the first case, develop heat by friction, and, in the second case, by augmenting the agitation of the molecules with which it collides.

In other words, we assume that a movement of electricity from a point P_1 to a point P_2 will manifest the energy involved in its passage along a potential gradient in the form of heat, *provided the charge does not move in a vacuum,* and it may be assumed that the same quantity of heat is developed, whatever be the mechanism of the transfer from P_1 to P_2, provided no work is done in producing a permanent chemical separation of atoms nor in generating electromagnetic radiation. Hence it follows that however we regard the details of the mechanism of metallic conduction we may expect the current to show the same heating effects.

By the simplest deductions the following ordinary relations are obtained: Calling I the current and t the time,

$$P = \frac{W_2}{t} = IV = \text{the power} \ldots\ldots\ldots\ldots\ldots\ldots (16)$$

The work done in the unit of time is

$$W_2 = IV = JH, \ldots\ldots\ldots\ldots\ldots\ldots (17)$$

where J is Joule's equivalent and H the quantity of heat. By Ohm's law the potential is

$$V = IR.$$

Hence

$$H = \frac{I^2R}{J} \ldots\ldots\ldots\ldots\ldots\ldots (18)$$

If R is taken in ohms, I in ampères, then H, in gramme calories per second, becomes

$$H = 0.24\, RI^2 \qquad (19)$$

Process of Electronic Transfer.

As we have shown that whatever be the process or whatever be the path by which electrons move from P_1 to P_2 the work done by the electric forces is the same, it is unnecessary to consider in detail the process whereby the conductor is heated by the passage of the current.

The process of electronic transfer may be considered from a physical point of view as follows:

It is assumed that when the temperature is not extremely high (1000° C. or higher) all the electrons in the metal are held attached by attractive forces to atoms or to atomic groups, and participate with the atoms or the atomic groups in their heat motions. It is also assumed that if any cause detaches an electron from an atom, the atom becomes a positively-charged body and exhibits all of the electrical properties of a small positively-charged particle.

It is further assumed that under electric stresses of ordinary intensity an electron will only leave one atom and pass to a near-by atom when, by the heat motions of the atoms or by an increase in the closeness of packing of the atoms (which results from an extreme lowering of temperature, great pressure, or both), two atoms or groups of atoms come within a certain very small distance of each other, which we shall call the contacting distance. In other words, metallic atoms, and several atoms when united into groups to form molecules, behave as perfect conductors, and the spaces between groups of atoms behave as perfect insulators. In considering an atom as a perfect conductor it is unnecessary to conceive that an electron can pass through an atom on the line of a diameter, but only that it can pass without restraint from a side of an atom facing the left to a side facing the right, perhaps by sliding without resistance over the surface of the atom.

This last assumption is not intended to preclude the possibility of an electron becoming detached from an atom by the violent collision of two atoms. This may occur, and before the electron can attach itself again to the same or another atom it may be swept out of the metal along the line of a very steep potential gradient. As an example of this occurrence, when a metallic filament (tungsten wire) is raised to a high temperature in a vacuum the atoms collide violently with one another, and electrons become momentarily torn off from some of the atoms. If there is now an electric stress, which acts radially to the filament, and the gradient of this stress exceeds the stress between a detached electron and the nearest positively-charged atom the electron is swept out of the attraction of the nearest positive atom along the line of the electric stress and becomes one of the carriers in the well-known thermionic current. We assume this to be the process in the production of the thermionic current in the Coolidge X-ray tube.

If a heated wire is in an atmosphere instead of in a vacuum, the atmosphere surrounding the wire is ionized both by the violent collisions of its molecules and by the bombardments of electrons forced out of the wire by an electric stress. If the electric stress is removed, our theory assumes that an electron which might become momentarily free will attach itself to the first positively-charged atom, molecule, or group of atoms with which it comes into close proximity, and when attached will move with the atom or molecule as this moves unless again knocked off by a violent collision.

We may now attempt to derive a formula based upon the above physical ideas and assumptions for the conductivity or resistivity of a pure metal. As shown above, no single formula can express the physical facts of the conductivity of a pure metal from the absolute zero of temperature to the boiling-point of the metal, and the first formula which we shall derive may only be expected to apply, even approximately, over the temperature range in which the metal is molten and only for those metals which are normal in their behavior, having a resistivity curve of the same type, as lead.

Assume a_1, a_2, a_3, a_4 to be a single row of groups of atoms, which we shall call molecules.

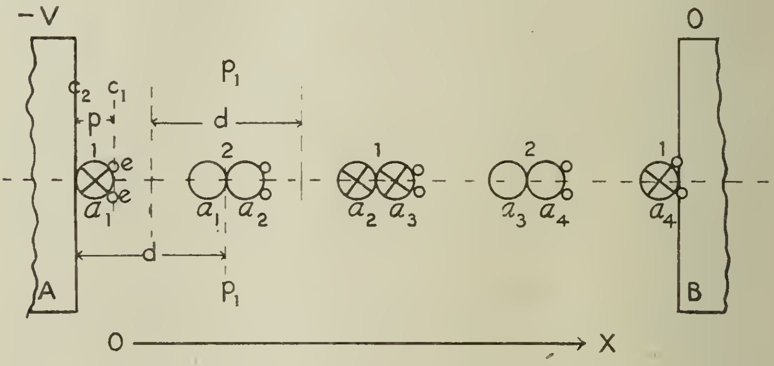
Assume that these molecules are oscillating in the line $O-X$, and move from position 1, designated in Fig. 5 by ⊕, to position 2, designated by ○.

Assume that, attached to and carried on the surface of each molecule are a number of electrons (two in the figure), and that, when there is no electric stress, each molecule is electrically neutral.

First consider the function in transporting electrons, of the four molecules represented in Fig. 5 as oscillating accurately in the same line parallel to $O-X$. Let there be an electric stress of intensity F in the direction $X-O$. At zero time assume the molecules to be in position 1. Then at this time a_1 receives k electrons from plate A.

It appears reasonable to suppose that the number of electrons which a_1 receives from plate A will be proportional to the intensity F of the electric field in the direction $X-O$; for we may consider that electrons will continue to collect upon the side of a_1 facing plate B until they are in sufficient number to produce an electric field equal in intensity and opposite in direction to the external electric field. There will then be zero potential difference (from c_2 to c_1) between the sides of a_1 facing A and facing B, and then there will be no further force acting to move electrons. As the potential difference, due to the external field from one side to the other of a molecule in the line $X-O$, will be proportional to the diameter of the molecule, we can say further that the number of electrons k to pass from plate A to the right side of molecule a_1 will be proportional to the diameter of the molecule. Call the diameter of each of the molecules ρ. We should then have $k \propto \rho F$. At time t_1 let a_1 collide with a_2. We may assume that at the moment of this collision a_2 receives from a_1 the extra electrons which it acquired from plate A. It receives these elec-

FIG. 5.



trons, which at once pass to the side of a_2 facing B, on account of the fall of potential over the diameter of a_2 due to the external electric field. At the same time a_3 will also be colliding with a_4, which likewise received k electrons from a_3.

At time t_2, a_4 will have returned to plate B and a_1 to plate A, and the k electrons on a_4 will have been delivered to plate B.

Thus in each interval of time δt the molecules will all have made a double excursion and k electrons will have moved in an opposite direction to the electric stress a distance $2d$ equal to twice the average distance between centres of molecules lying in the line of the electric stress.

The quantity of electricity which moves in this interval will be proportional to the number of electrons, $k \propto \rho F$, and to the charge e carried by an electron. Calling δq the quantity of electricity transported by a single row of molecules in the interval δt, we then have

$$\delta q \propto \rho e F \qquad (20)$$

In the unit of time the molecules will make, on the average, $\mu = \frac{1}{\delta t}$ double excursions, and hence the quantity of electricity to be transported in the unit of time by a single row of molecules will be

$$\mu \delta q = \delta Q \propto \mu \rho e F \qquad (21)$$

This is the quantity of negative electricity to cross any plane as $p_1 - p_1$ drawn perpendicular to the line of the electric stress in the unit of time, and this is the electric current. Hence if we call δi this current we have

$$\delta i \propto \mu \rho e F \qquad (22)$$

Dividing the current by the electric force per unit length gives the conductance, which in this case is to be considered as the conductance per unit length due to a single row of molecules. Calling this quantity δc, we derive,

$$\frac{\delta i}{F} = \delta c \propto \mu \rho e \qquad (23)$$

If we assume that over the unit of area of any plane drawn perpendicular to the electric stress there are, on the average, w molecules colliding in the above manner with average frequency μ, we can write in place of δc, the conductance for a single row of molecules, σ, the conductivity, or conductance through unit cross-section per unit length. We shall then have, as an expression for the conductivity of the material,

$$\sigma \propto w \mu \rho e \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (24)$$

We are ignorant of all the quantities on the right side of equation (24) except *e,* the electronic charge. It would be impossible, therefore, to obtain an accurate numerical confirmation of this relation. It is possible, however, by making certain additional assumptions which appear reasonable, and which, at least, are not artificial, to deduce from the relation 24 another expression for the conductivity of a pure metal which may be compared in several particulars with facts experimentally ascertained.

Let us suppose the metal to be in the liquid state. Call N the number of molecules, or atomic groups, in a unit cube of the material when at temperature θ. Let us consider only the component of velocities which these molecules have in the direction of the electric stress, as this is the only component which transmits electrons. Let the average velocity of the molecules in the line of the electric stress be called v. Now w, the number of encounters which take place over the unit of area at a given instant, will be proportional to the probable number of collisions of molecules moving to the right with molecules moving to the left.

If we call r the radius of a molecule, an encounter will occur whenever two oppositely moving molecules lie on the same plane a distance $2r = \rho$ apart. Then when an encounter between two oppositely moving molecules just occurs by tangential contact, the area occupied upon the plane of contact by these two molecules is $a = 2\pi r^2$, and the total area on the plane of contact occupied by molecules so located as to make a contact possible is

$$A_t \propto Na \propto N\pi r^2.$$

As the total area of the plane is taken as unity and A_t is the portion of the total area favorable to a contact, we obtain for the probability of a contact,

$$P \propto \frac{A_t}{1} \propto N\pi r^2 \propto N\rho^2 \ldots\ldots\ldots\ldots\ldots\ldots (25)$$

where ρ is the diameter of a molecule. But this probable number of contacts is proportional to the quantity w in equation (24), which may now be written,

$$\sigma \propto N\rho^3\mu e \qquad (26)$$

Calling m the mass of a molecule and v its average velocity, its kinetic energy will be $\frac{1}{2}mv^2$, and this energy will be proportional to the absolute temperature θ of the metal. From this we derive $v \propto \frac{\theta^{\frac{1}{2}}}{\sqrt{m}}$. Now the average distance through which any molecule can oscillate will be equal to $d-\rho$ (Fig. 5) where d is the average distance between centres of molecules having the diameter ρ.

We may then write,

$$\mu = \frac{v}{d-\rho} \propto \frac{\theta^{\frac{1}{2}}}{(d-\rho)\sqrt{m}} \qquad (27)$$

and by substituting this value of μ in equation (26) our expression for the conductivity becomes

$$\sigma \propto \frac{N\rho^3 e\, \theta^{\frac{1}{2}}}{(d-\rho)\sqrt{m}} \qquad (28)$$

or the expression for the resistivity becomes

$$\rho_1 \propto \frac{(d-\rho)\sqrt{m}}{N\rho^3 e\, \theta^{\frac{1}{2}}} \qquad (29)$$

Equation (28) tells us that the conductivity of a metal for *constant volume* and *constant number of molecules* should increase as the square root of the absolute temperature. The interpretation to be put upon this is that the *resistivity* of a metal should grow less with increase in temperature, *provided the pressure is maintained so that the volume of the mass does not change.* This decrease in resistance with temperature is found, in fact, to be the case with liquid mercury, according to the statements of Charles A. Kraus. He shows[4] "that when liquid mercury at 20° C. is heated at constant volume its resistance *decreases* by 0.069 per cent. per degree, whereas when heated at constant pressure its resistance *increases* 0.089 per cent. per degree," and he concludes that "*the increase in resistance of liquid mercury with increasing temperature is due to its decrease in density.*"

---

[4] *Physical Review,* vol. iv, September, 1914, p. 161.

It is also a rather significant fact that pure graphite, which has an extremely small expansion, decreases slightly in resistance with increase in temperature.

As ordinarily made, the measurement of the resistance of a liquid metal is taken between potential points located on a column of the metal, and the pressure is atmospheric and constant. As the temperature rises the metal expands, and this expansion certainly increases the average distance d between centres of the molecules. How much the proportionate increase between centres of molecules is we do not know certainly, and it is useless to make assumptions so chosen that for any particular metal the expression for the resistivity would agree with the experimentally-gotten curve for the metal. We can profitably assume, however, that d increases as the density of the metal decreases.

The factor $\sqrt{m}$ shows that on this theory the resistivity should be large for metals of large molecular weight, though the occurrence of the factors N and ρ^3 in the denominator of equation (29) makes this conclusion uncertain. However, in a very general way such seems very roughly to be the case. Thus lead, with an atomic weight of 207.1, has a resistivity at 20° C. of about 21 microhms, and tin, with an atomic weight of 119, has a resistivity of 11.4. The atomic weight of potassium is 39.1 and its resistivity is 7.11, and the atomic weight of sodium is 23 and its resistivity is 4.87. The atomic weight of gold is 197.2 and its resistivity is 2.44, and the atomic weight of copper is 63.57 and its resistivity is 1.72. These figures do not mean much, however, as the molecular weights in the solid state are unknown.

Since the cubical expansion of some metals has been determined through considerable ranges of temperature, it seems permissible to make the assumption that $d = d_0 + 3a\theta$ where d_0 is the distance between centres of molecules at 0° K., and a is the coefficient of linear expansion. But when the molecules are absolutely at rest, as they are supposed to be at the absolute zero, we would have $d_0 = \rho$, the diameter of a molecule, and we obtain

$$d = \rho + 3a\,\theta \qquad \text{(30)}$$

Substituting this value of d in equation (29), we obtain

$$\rho_1 \propto \frac{a\sqrt{m}\,\theta^{\frac{1}{2}}}{N\rho^3\,e} \qquad \text{(31}$$

Further, let N_0 be the number of molecules in the unit of volume at 0° K. Then if N is the number of molecules in the unit of volume at the temperature θ, we have $N = \frac{N_o}{V_\theta}$, where V_θ is the volume to which the unit of volume expands at $\theta°$. If we assume that the expansion is proportional to the temperature, then $V_\theta = 1 + b\,\theta$ and $N = \frac{N_o}{1 + b\theta}$, which value substituted in equation (31) gives

$$\rho_1 \propto \frac{a \sqrt{m}\, \theta^{\frac{1}{2}} (1 + b\theta)}{N_o \rho^3 e} \qquad \text{(32)}$$

Since the coefficient b of cubical expansion is three times a, the coefficient of linear expansion, equation (32) can also be written:

$$\rho_1 \propto \frac{\sqrt{m}\, a(1 + 3a\theta)\theta^{\frac{1}{2}}}{N_o \rho^3 e} \qquad \text{(33)}$$

Equation (33) is of the form

$$\rho_1 = K\,(\theta^{\frac{1}{2}} + b\,\theta^{\frac{3}{2}}) \qquad \text{(34)}$$

where K is a constant and b is the cubical coefficient of expansion of the metal. It is here assumed that this coefficient is reckoned from the absolute zero of temperature, and that the metal expands by a linear law. Then if the volume of a liquid metal is V_{θ_1} at the absolute temperature θ_1 and V_θ at a lower absolute temperature θ

$$b = \frac{V_{\theta_1} - V_\theta}{V_\theta \theta_1 - V_{\theta_1} \theta} \qquad \text{(35)}$$

From data obtained by Day, Sosman and Hostetter[5] we obtain for the value of the coefficient of lead, $b_{Pb} = 124.1 \times 10^{-6}$, and for tin $b_{Sn} = 103.6 \times 10^{-6}$. We substitute these values in equation (34), and so choose the constant K that the resistivity obtained from equation (34) at the temperature 1000° K. shall be the same as the value obtained by experiment. In doing this we find $K = 3.181$ for lead, and $K = 1.712$ for tin. We then make plots of Equation (34) for lead and tin and obtain the theoretical curves for lead and tin given in the curve sheet Fig. 2. These curves below temperatures where the metals are molten are shown in dotted lines because equation (34) cannot be expected to apply below a point where a metal changes from liquid to solid.

---

[5] "The Determination of Mineral and Rock Densities at High Temperature," *American Journal of Science*, vol. xxxvii, January, 1914.

If our theory was faultless the theoretical curves should be straight lines after the metals melt and should have the same slants as the experimental curves. These results are only approximately realized. The experimental curve for lead shows an increase of 0.0455 microhm per degree, while the theoretical curve shows an increase of about 0.066 microhm per degree. The corresponding figures for tin are: experimental, 0.0246; theoretical, about 0.033.

The writer considers that these results indicate that our hypotheses fail to account for all the factors which are involved in a change in resistance with temperature of a molten metal, but that, on the other hand, the general character of the curve confirms more than it discredits the theory in its broad outlines.

It remains to inquire if, according to the above theory, any reasonable explanation can be proposed which will account for the sudden change in resistance which takes place in a pure metal when it melts.

It requires a very considerable input of energy to change a metal from the solid to the liquid state, but the process involves no change in temperature. Thus to convert 1 gramme of Al from solid into liquid requires 77 gramme-calories, Pb requires 5, Sn 14, Hg 3, Cu 43, Bi 13, Ag 22, Zn 28. No relation appears to exist between these various inputs of energy and the change which takes place in the resistivity of the metal when it melts, and according to our hypotheses we must look for the change in resistance as due chiefly to a change, upon fusion of the metal, in the number of atoms which constitute an atomic group. We conceive, as it requires no change in temperature for a metal to pass from solid to liquid, that the energy which must be put into the metal to bring about fusion is used in breaking up aggregations of atoms capable of oscillating together as a group into aggregations consisting of a less number of atoms which oscillate as a group. We may assume also that, in those metals which expand in liquefying, a part of the energy is used in expanding the metal. In other words, the latent heat of fusion is stored when a metal melts as potential energy of separation of its atoms. We may not only think of the atomic groups as consisting of a smaller number of united atoms when the metal is molten, but may consider that these groups are free to wander about in the fluid metal, and, not being held in fixed relations to each other by attractive forces, that the proportionate number of atomic groups which collide in a given time, and so allow electrons to pass from one to another, is much less in the molten metal than in the solid metal. Further than this it is unprofitable to speculate with our present state of knowledge. Experiment shows us that in most cases the ratio $\frac{\rho_1}{\rho_s}$, namely, the resistivity of the metal just after fusion to its resistivity just before fusion, is about 2 when the metal expands on liquefying and about ½ when it contracts on liquefying.

To a certain extent we can express these ideas in symbolic form by making use of equation (29).

Let $\rho_l \propto \frac{(d-\rho)\sqrt{m}}{N\rho^3 e\theta^{\frac{1}{2}}}$ express the resistivity of the metal just after fusion. We know that when the metal gives up its latent heat of fusion and becomes solid at the same temperature there is no reason to suppose that the quantity e changes. Since d is the distance between centres of atomic groups we should expect d to change, becoming less, due to an increase in density of the metal, and larger due to the assumed fact that the atomic groups of the solid metal are larger and hence have their centres further separated. We should expect ρ, the diameter of an atomic group, to be larger in the solid, and also m, the mass of an atomic group. The number of atomic groups N in the unit of volume would increase from an increase in density of the metal, but decrease from the assumed fact that each group is made up of an increased number of atoms to the group. Writing a prime mark on those quantities which change, calling ρ_s the resistivity of the metal when solid and ρ_l when liquid, and taking the ratio of ρ_l to ρ_s we have

$$\frac{\rho l}{\rho_s} = \frac{(d-\rho)\sqrt{m}\, N'\rho'^3}{(d'-\rho')\sqrt{m'}\, N\rho^3} \dots\dots\dots\dots (36)$$

If we further assume that $m \propto \rho^3$ and $m' \propto \rho'^3$, we obtain

$$\frac{\rho l}{\rho_s} = \frac{(d-\rho)N'\rho'^{\frac{3}{2}}}{(d'-\rho')N\rho^{\frac{3}{2}}} \dots\dots\dots\dots (37)$$

As stated above, this ratio is greater than unity in most cases and less than unity in the exceptional cases of antimony and bismuth.

It may be noted that if the solid metal were cooled to the absolute zero we should expect $d' = \rho'$. In this case the ratio becomes infinity, as it should, according to experiment.

The above discussion of the facts of metallic conduction and the hypotheses which have been proposed to account for these facts touches the general problem of electrical conduction in only a few places. The accumulation of experimental evidence is not yet sufficient to make a longer or a more detailed discussion of metallic conduction profitable, and a further discussion of the general problem of electrical conduction, including such topics as the resistivity of insulators, the relations of electrical and thermal conductivity, the subjects of thermal electromotive force, the Peltier effect, the Thomson effect, the Hall effect, thermionics, and the conduction through hot gases at atmospheric pressure, would entirely transcend the purpose and assigned limits of this article.

It is thought that the most sound and fruitful increase in our knowledge of the relation between electricity and ordinary matter will come from an extended experimental investigation and by interpreting and coördinating the facts and phenomena revealed by experiment. This method, in which the characteristic elements of revealed phenomena are mentally abstracted and their essential likenesses and dissimilarities are observed, will do more for the advancement of science than propounding theories to which mathematical expression may be given, especially when logical developments of such theories rest upon assumptions of the existence of conditions essentially artificial.

Palmer Physical Laboratory, Princeton, N. J.,
March 24, 1915.

SOUND STEEL FOR RAILS AND STRUCTURAL PURPOSES.

BY

SIR ROBERT A. HADFIELD, F.R.S.,
Member of the Institute.

[SECOND COMMUNICATION]

SINCE the author contributed his paper on "Sound Steel for Rails and Structural Purposes," which appeared in the February JOURNAL OF THE FRANKLIN INSTITUTE, he has completed the instructions of the Pennsylvania Railroad Company to produce for them one hundred tons of ingots made under his sound steel system. These ingots were made at the works of his firm in Sheffield, full particulars being given in Plate I and Table 1. The table gives the analyses of the various ingots, also an exact record as to the cubic capacity of the cavity or sinking head portion at the top of each ingot. So far as the author is aware, there has never before been such careful preparation of a considerable number of ingots to be rolled into rails. The methods of manufacture have been fully described in the previous paper to this Institute and elsewhere, as shown by the accompanying bibliography.

It will therefore be interesting to see how the rails produced from these ingots behave when put to use. It is probable they will give the best results yet obtained in any country, no matter how severe the service may be, because the material from which they are made is perfectly sound, free from blowholes, segregation, and piping. Moreover, the result of this research relating to the question of the soundness and suitability of such steel for producing *safe* rails will be, no doubt, to show that it is possible that by the use of this sound steel rails of the highest quality will be obtained, and this with very little addition, if any, to their cost. In fact, when working on a large scale, it is probable the cost will be reduced.

The joint paper by Dr. G. K. Burgess, of the National Standards Bureau, and the author on "Sound Steel Ingots and Rails," read before the American Institute of Mining Engineers, also on the same subject read before the Iron and Steel Institute in London, May, 1915, shows the superior quality obtained by the soundness and freedom from segregation of this type of ingot. This was fully borne out in the actual appearance of the rails produced from such ingots for the research in question. It was also noted that the rails broken up and used for test showed superiority in their nature and quality, not only as regards finish, but in their chemical, mechanical, drop, and other tests. All these points are fully set forth in the joint paper above mentioned, and as regards the steel side of the question they are further dealt with by the author in the paper on "Sound Steel for Rails and Structural Purposes," published in the JOURNAL OF THE FRANKLIN INSTITUTE of February, 1915.

To further illustrate these facts, the main observations in the joint research above mentioned are shown in the following remarks, which, it may be mentioned, are statements not made by the author of this paper, but by his collaborator in the previous research, Dr. G. K. Burgess, of the National Standards Bureau, Washington:

REMARKS BY DR. G. K. BURGESS REGARDING THE COMPARISON OF TWO SPLIT INGOTS.

"Ingot 'A,' made under the Hadfield system, is perfectly sound, free from blowholes, piping, and segregation.

"Ingot 'B,' of American make, is unsound and contains blowholes, piping, and segregation."

Ingot "A," cast by the feeding method, was split or sliced open vertically on the axis line, and presents a smooth, clear surface, free from segregation, pipe, seams, blowholes, or other imperfections.

Ingot "B," representing the average ingot, was split open in the same manner and presents the usual piped appearance, nearly one-half being unsound and unsuitable for rolling into rails, whereas the ingot cast by the feeding method is sound throughout.

In other words, a discard of fifty per cent. would be necessary for this comparison ingot "B," and only about ten per cent. in the case of the ingot "A"; that is, there would be but little discard below the feeding head.

A sulphur print taken of one-half of the vertical section of the ingot " A " indicates very uniform distribution of the constituents in the metal, and practically freedom from segregation.

As would be expected, ingot " B," with its pronounced pipe, shows marked segregation of carbon, phosphorus, and sulphur in the piped region to a depth of nearly fifty per cent. from the top of ingot, and other regions of somewhat varying composition. The manganese shows but slight segregation anywhere.

This examination shows the great superiority of the ingots cast by the Hadfield feeding process, such ingots being physically sound and uniform throughout, also free from segregation.

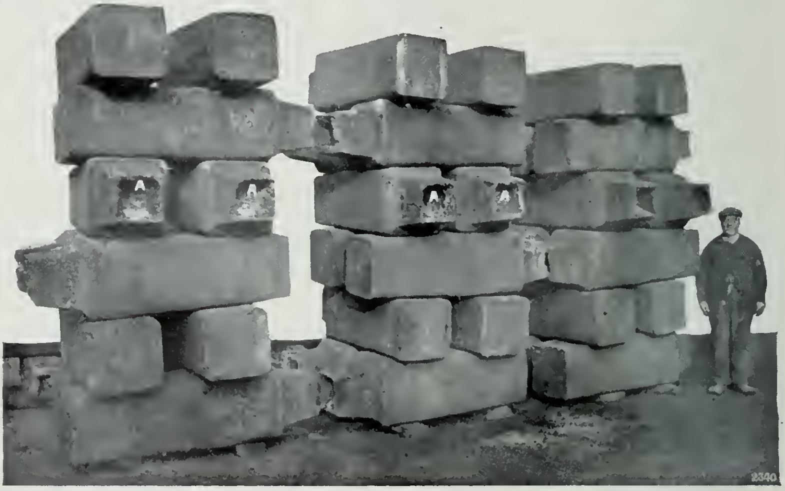
These two ingots were rolled into rails by the Maryland Steel Company, Sparrow's Point, and the following further comparisons are also stated by Dr. Burgess:

> Uniform hardness, determined by a large number of Brinell ball hardness tests, is shown over the whole series of rails from the Hadfield ingots, whereas rails from the ordinary ingot do not possess this uniform quality.
>
> The " A " rail from the Hadfield ingot is sound—beautifully so—right up to the front end or to the " bloom crop " itself. The ordinary ingot is unsound at the same portion of the ingot.
>
> The web, which is usually the part consisting of the poorest material, is practically uniform in the case of the Hadfield ingots with the remainder of the section.
>
> Examination of the rails shows that the ingots made by the Hadfield process will give rails of uniform quality, free from flaws of all kinds.
>
> Drop tests on the rails from the Hadfield ingots show a high degree of uniformity of resistance to shock.

The above independent examination and observations by Dr. Burgess are a remarkable confirmation of the statements made by the author during the last few years with regard to the advantages obtained by the use of sound steel.

A proof of this soundness is shown in Table I, column 10, headed " Capacity of cavity," in which is set forth the amount of cavity in the head of each of the ingots cast by the Hadfield system. A further description of the nature of this cavity was given in the JOURNAL OF THE FRANKLIN INSTITUTE of February, pages 110 to 140. It is also still more clearly described in Plate II now given, also at "A" in Plate I accompanying this paper. Column II of Table I gives the same information worked out in percentage figures. The uniformity of these ingots is shown by this means in a remarkably clear manner; also that each ingot is perfectly sound, free from blowholes, with no piping and no segregation below about ten per cent. discard; in fact, even with eight per cent. discard the segregation is practically of no importance. Ordinary ingots for rails or other purposes show no such cavity, and it is quite impossible to determine from the outside portions of the ingot whether it is good or bad. In every ingot made under the writer's system it is possible to know that it is good. If for any reason a bad heat has been used, then an

PLATE I.



Thirty-six 18-inch rail ingots, weighing about one hundred tons, made for the Pennsylvania Railroad. 5 feet 4 inches in length. Weight, 5380 pounds each.

These ingots have been made under the Hadfield system of producing sound steel.

Each of these thirty-six ingots is sound, entirely free from blowholes, segregation, or piping. After cutting off about 10 per cent. of the ingot, the whole of the remainder of the steel is available for producing perfectly sound rails. Fuller particulars of the exact amount of settling as represented by the cavities *A* for each of these thirty-six ingots is shown on the accompanying Table I. The average capacity of the cavity for each ingot is 9943 cubic centimetres,—that is, 3.19 per cent. of the weight of the ingot. The weight of the fluid steel which has passed from the head portion into the ingot itself is about 130 pounds. In ordinary ingots the greater part of this material remains in the upper portion of the ingot and does not feed the piping or settling which occurs, whereas in these ingots this takes place, enabling the extraordinary soundness mentioned to be obtained.

TABLE I.

Ingots Made for the Pennsylvania Railroad by the Hadfield System of Producing Sound Steel.

Ingot No. and mark.	Heat No.	Analysis					Head particulars			
		C	Si	S	P	Mn	Height to which filled in head, inches	Depth of settling, inches	Capacity of cavity, c.c.	Percentage of settling to total bulk of ingot
1	2	3	4	5	6	7	8	9	10	11
1	4588	.64	.19	.047		.97	13	7¼	8.930	2.86
2	4600	.65	.15	.049		.96	13½	8½	9,825	3.16
3	4615	.64	.20	.048		1.01	14¼	7	9,000	2.89
4	4627	.64		.052		.97	14	8¼	9,600	3.08
5	4641	.67 .69		.045		.94 .92	14½	8½	9,000	2.89
6	4653	.61		.053		.85	13½	7¾	9,900	3.17
7	4668	.58		.042		.93	14½	8½	10,100	3.24
8	4680	.65	.14	.049	.029	.92	13¾	8½	10,250	3.29
9	4696	.66		.038		.96	13½	6½	8,600	2.77
10	4709	.58		.049		.93	13	7¾	8,930	2.88
11	4723	.63		.044		.95	13½	8	9,900	3.17
12	4738	.63 .64		.042		.91	13½	9	10,300	3.31
13	4761	.65		.048		.90	13½	8½	10,800	3.47
14	4774	.65		.040		.94	14	8¼	9,950	3.19
15	4801	.66		.036		.95	13½	8⅛	9,150	2.90
16	4813	.64	.14	.048	.032	.93	14	8⅝	10,800	3.45
17	4825	.66		.045		.92	13½	6⅞	9,000	2.89
18	4829	.66		.041		.98	14	8½	11,100	3.55
19	4835	.69		.046		.91	13½	7¾	9,520	3.05
20	4847	.63 .64		.047		.93	13¾	9¼	10,450	3.37
21	4861	.62 .61	.21	.045	.031	.92	14	9⅝	10,900	3.49
22	4873	.69		.050		.95	14	9⅜	10,250	3.29
23	4887	.63		.050		.89	14	9	10,500	3.36
24	4908	.64		.041		.84	14	8¾	9,750	3.11
25	4915	.65 .66		.049		.02	14	9¾	9,675	3.10
26	4939	.63 .64	.16	.045	.028	.92	13	7½	8,800	2.84
27	4978	.67 .68		.051		.96	14½	9⅞	9,260	2.95
28	4992	.66		.045		.94	13½	9¾	9,000	2.88
29	5004	.65		.052		.94	14	8½	10,175	3.27
30	5018	.64	.16	.039	.031	.92	14	8¾	10,040	3.21
31	5030	.60		.056		.94	13½	10⅛	11,950	3.82
32	5046	.63 .62		.042		.93	13½	7	10,500	3.37
33	5059	.63 .64		.049		.92	14	8⅞	10,750	3.44
34	5073	.64 .63		.045		.90	14	9½	10,500	3.37
35	5085	.63 .64	.16	.042	.031	.86	13¼	9¼	11,000	3.52
36	5099	.63 .64		.039		.86	11	8⅞	10,040	3.34
37	4787	.67		.045		.88	13¾	7⅜	8,125	2.58 cut up
1	2	3	4	5	6	7	8	9	10	11
Minimum		.58	.14	.036	.028	.84	11	6½	8,600	2.77
Maximum		.69	.21	.053	.032	1.01	14½	10⅛	11,950	3.55
Average		.64	.16	.046	.030	.92	13¾	8¼	9,943	3.19

The total weight of these ingots amounts to 96 tons.

inspector can detect this in the ingots themselves, either in a hot or cold condition. There is, however, no reason to have any bad ingots of this nature. The steel maker by the preliminary test knows this before he pours the steel.

Plate II represents one of the thirty-six eighteen-inch ingots prepared by the author, taken from the 100-ton lot prepared for the Pennsylvania Railroad. This ingot was sliced for its full length. Its analysis was as follows:

C	Si	S	P	Mn
0.67	0.18	0.045	0.03	0.88 per cent.

This ingot is of perfectly sound structure, and represents the same high quality of each of the thirty-six ingots sent by the instructions of the Pennsylvania Railroad to be rolled into rails. After cutting off about ten per cent. discard the whole of each of these thirty-six ingots can be worked up into sound and safe rails. The same remark would just as well apply to thirty-six million of such ingots!

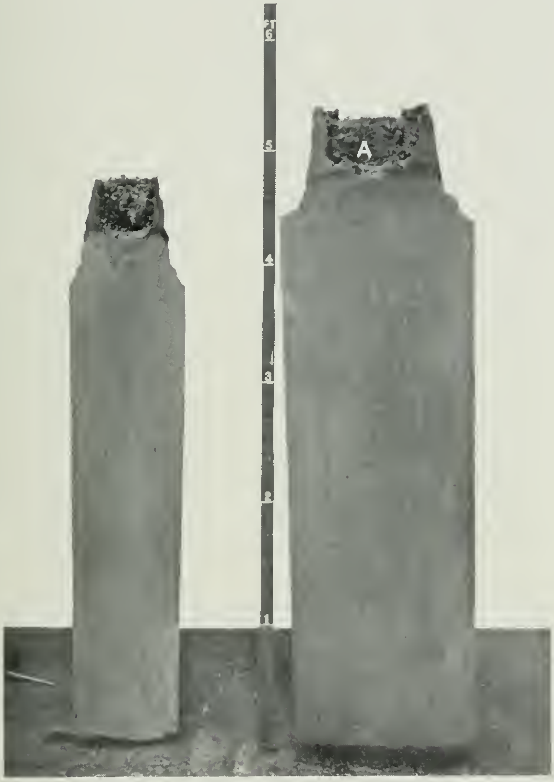
The capacity of the cavity of the ingot (shown in Plate II) which was cut up, and at the part marked "A," was 8125 cubic centimetres, the percentage of settling to the total weight being 2.58 per cent. The weight of material which passed from the head portion into the ingot itself was about 130 pounds. It is exactly this portion of the fluid steel being properly applied, that is acting as feeding material to the body of the ingot, which makes the difference between ordinary and these special ingots.

This ingot was selected because it showed the lowest cavity percentage of the series. The slight variations in the percentage of settling, and therefore difference in the cavities, are of no importance. For example, the sand heads may vary slightly in height, or the steel may not be poured to just the same height. In such cases the ingots with the shortest length of head will necessarily have the smallest capacity. Nevertheless, as the figures show, the average percentage of the cavity is remarkably uniform.

In ordinary ingots, even of piping nature, probably not more than one-third of the fluid steel at the top or upper portion passes into the body of the ingot, consequently it is quite easy to understand why unsound and piped places, also general looseness of structure, occur for a long way down the ingot. This is the secret of the reason why it is necessary in such ordinary ingots to have discards varying from thirty per cent. to forty per cent., and in some cases even more, in order to get rid of unsoundness, piping, and segregation; whereas in the ingots made on the writer's plan only about eight or ten per cent. is necessary.

PLATE II.

FIG. 1. FIG. 2.



Ingots made under the Hadfield system of *producing sound* steel.

11-inch mild steel ingot.

Heat No. 4952/3194 of the following analysis:

C.	Si.	S.	P.	Mn.
.18	.06	.044	.031	.88

18-inch ingot.

Heat No. 4787/3191 of the following analysis:

C.	Si.	S.	P.	Mn.
.67	.18	.045	.03	.88

Sliced open upon the full transverse length.

This ingot is representative of the 36 ingots sent to be rolled into rails. The capacity of the cavity of this ingot at *A* was 8125 cubic centimetres, and the percentage of "settling" to the ingot was 2.58.

Plate I shows the thirty-six eighteen-inch ingots, five feet four inches in length, weighing about 5380 pounds each, made for the Pennsylvania Railroad. Each ingot is perfectly sound and free from blowholes, segregation, or piping, and no less than about ninety per cent. of this material is available for producing perfectly sound billets. The exact amount of settling as represented by the cavities, marked "A," is given in full for each of the ingots in Table 1. The average capacity of the cavity for each ingot is 9943 cubic centimetres; that is, 3.19 per cent. of the weight of the ingot. In each of these ingots about 140 pounds of the fluid steel pass into the body of the ingot.

Table 2.

Analysis of Samples Taken from Ingots Made by the Hadfield System for Producing Sound Steel Free from Porosity, Piping, and Segregation.

The following analyses were taken from the ingots referred to in the table given below. In this case the discard from each ingot was fifteen per cent.

All the ingots were made under government inspection. The following are the analyses by the government chemist:

Heat Nos.	C	Si	S	P	Mn
	Billets for small-calibre projectiles.				
S. 1277	.37	.17	.042	.032	.90
S. 1278	.36	.19	.032	.030	.85
S. 1298	.39	.22	.030	.032	.84
S. 1299	.36	.22	.029	.029	.86
Maximum	.39	.22	.042	.032	.90
Minimum	.36	.17	.029	.029	.84
Average	.37	.20	.033	.030	.86
	Billets for small-calibre projectiles.				
S. 1153	.39	.17	.033	.040	.95
S. 1154	.39	.15	.036	.040	.89
S. 1155	.37	.24	.038	.040	.94
S. 1156	.38	.18	.034	.045	.89
S. 1157	.40	.20	.034	.044	.93
Maximum	.40	.24	.038	.045	.95
Minimum	.37	.15	.033	.040	.89
Average	.38	.19	.035	.042	.92

Table 2.—*Continued.*

Heat Nos.	C	Si	S	P	Mn
	Billets for large-calibre projectiles.				
S. 1322	.42	.20	.040	.037	.86
S. 1321	.44	.17	.041	.036	.87
S. 1320	.49	.20	.038	.036	.87
S. 1309	.39	.23	.036	.031	.77
S. 1308	.50	.21	.033	.031	.80
S. 1307	.40	.22	.033	.031	.86
S. 1306	.49	.19	.033	.032	.85
S. 1305	.46	.24	.034	.032	.86
S. 1304	.51	.18	.036	.031	.83
S. 1303	.45	.25	.036	.031	.86
S. 1301	.36	.21	.035	.025	.83
S. 1300	.38	.21	.034	.025	.81
S. 1289	.38	.25	.040	.034	.89
S. 1288	.43	.15	.039	.029	.84
S. 1284	.41	.24	.036	.032	.83
S. 1281	.44	.26	.034	.030	.92
S. 1280	.39	.18	.036	.029	.87
S. 1269	.42	.16	.040	.034	.86
S. 1268	.40	.19	.036	.033	.86
S. 1267	.36	.21	.035	.032	.86
S. 1266	.41	.17	.040	.034	.84
S. 1265	.34	.18	.030	.027	.83
S. 1263	.43	.17	.037	.032	.86
S. 1252	.42	.25	.031	.031	.85
S. 1251	.34	.19	.045	.030	.83
S. 1250	.46	.18	.034	.033	.89
Maximum	.51	.26	.045	.037	.92
Minimum	.34	.15	.030	.027	.80
Average	.42	.21	.038	.032	.86

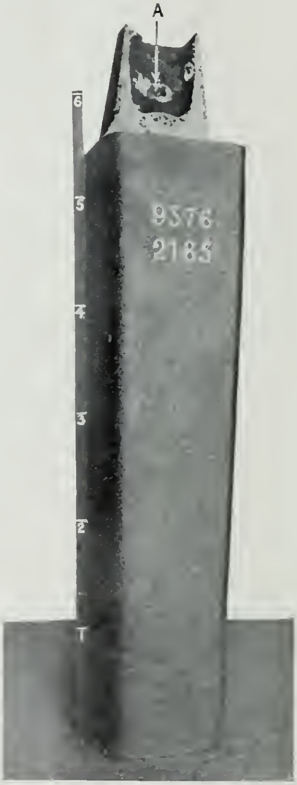
The remarkable uniformity of these ingots is shown. The whole of them were worked into projectiles in which not a single waster projectile resulted.

Plate III is of interest, as it shows the application of the system to the production of mild steel ingots containing only 0.18 per cent. carbon. The ingots for rails as shown in Table 1 contain an average of 0.64 per cent. carbon. This system is equally applicable to any kind of steel, whether plain carbon or alloy steel.

As further showing the quality of ingots made under this system, Table 2 gives analyses of samples taken from ingots in which a discard of fifteen per cent. was cut off from each ingot. The ingots were made under government inspection, and the analyses were taken by the government chemist. Table 3 gives the same information as regards another set of ingots in which twenty-five per cent. discard was cut from each ingot.

This particular experiment enables comparison to be easily drawn between ingots having (*a*) fifteen per cent. and (*b*) twenty-five per cent. discard. It will be seen that the analyses show that the material from the ingots with fifteen per cent. discard is fully equal to that with twenty-five per cent. discard; that is, with the lesser percentage there is no segregation. These particular ingots were used among many thousands for the manufacture of high explosive projectiles. The resulting projectiles were equally as good from the billets with fifteen per cent. as those made from twenty-five per cent. discard; that is, there was not a single waster in either case. Even with billets made from ingots with only ten to twelve per cent. discard the results would

PLATE III.



have been the same as obtained with fifteen per cent. discard. In other words, perfectly sound steel can be obtained with ten to twelve per cent. discard. In any case, even with fifteen per cent. discard, there is a great saving in material, loss of time, and the avoidance of remelting a large percentage of the ingot, as is now the case. It may be mentioned that from ingots made in the ordinary manner about forty per cent. is insisted upon, and this rightly so.

TABLE 3.

Analyses of Samples Taken from Ingots Made by the Hadfield System for Producing Sound Steel Free from Porosity, Piping, and Segregation.

The following analyses were taken from the ingots referred to in the table given below. In this case the *discard from each ingot was twenty-five per cent.*

All the ingots were made under government inspection. The following are the analyses by the government chemist:

Heat Nos.	C	Si	S	P	Mn
	Billets for small-calibre projectiles.				
S. 1213	.40	.18	.036	.032	.89
S. 1237	.38	.24	.035	.035	.89
S. 1238	.37	.24	.033	.035	.89
S. 1294	.39	.19	.036	.036	.84
S. 1295	.40	.26	.039	.035	.92
S. 1330	.39	.24	.036	.035	.86
S. 1331	.41	.19	.035	.032	.84
S. 1354	.37	.24	.038	.032	.92
Maximum	.41	.26	.039	.036	.92
Minimum	.37	.18	.033	.032	.84
Average	.39	.22	.036	.034	.88
	Billets for small-calibre projectiles.				
S. 1257	.40	.20	.033	.034	.88
S. 1259	.40	.20	.030	.034	.87
S. 1270	.40	.19	.041	.034	.86
S. 1271	.41	.22	.037	.032	.91
S. 1272	.41	.20	.035	.033	.86
S. 1273	.39	.27	.039	.037	.89
S. 1274	.38	.25	.042	.037	.91
S. 1275	.42	.20	.042	.037	.90
S. 1276	.40	.21	.042	.035	.91
S. 1279	.38	.21	.036	.036	.93
S. 1290	.41	.21	.034	.035	.88
S. 1291	.42	.26	.036	.035	.91
S. 1292	.40	.24	.036	.039	.87
S. 1293	.41	.24	.039	.037	.84

TABLE 3.—*Continued.*

Heat Nos.	C	Si	S	P	Mn
	Billets for small-calibre projectiles.				
S. 1310	.40	.26	.037	.037	.91
S. 1311	.40	.23	.035	.040	.92
S. 1312	.40	.23	.034	.033	.92
S. 1313	.39	.23	.032	.034	.92
S. 1314	.40	.19	.034	.036	.92
S. 1315	.39	.22	.036	.032	.87
S. 1316	.40	.21	.036	.033	.91
S. 1317	.39	.26	.038	.033	.93
S. 1318	.40	.21	.038	.033	.93
S. 1319	.38	.22	.037	.035	.90
S. 1337	.38	.28	.034	.030	.89
S. 1338	.40	.25	.034	.032	.84
S. 1339	.39	.22	.035	.032	.90
Maximum	.42	.28	.042	.040	.93
Minimum	.38	.19	.030	.030	.84
Average	.40	.23	.036	.035	.89

The remarkable uniformity of these ingots is shown. The whole of them were worked into projectiles in which not a single waster projectile resulted.

To work out this great improvement in definite figures, taking 100 tons as the basis, then from

(*a*) Ingots made in the ordinary manner there would be obtained about sixty tons of sound steel; that is, forty per cent. discard.

(*b*) Under the writer's method, with twenty-five per cent. discard there would be seventy-five tons of sound steel.

(*c*) Under the writer's method, with fifteen per cent. discard there would be eighty-five tons of sound steel.

(*d*) Finally, as above mentioned, with ten to twelve per cent. discard there would be about ninety tons of sound, usable product, a saving of no less than thirty tons as compared with ingots under "A"; that is, made in the ordinary manner.

To sum up the foregoing, if eighty-five to ninety tons of safe, usable material of the highest class can be obtained from 100 tons of ingots, what is the use, as at present practised, in making our steel furnaces produce ingots which require thirty to forty per cent. discard, when by using the system now referred to ten to twelve per cent. discard is quite safe and gives products of the highest possible value?

The world's output of steel for 1913 was estimated to be 75,000,000 tons. If a probable average waste of, say, twenty-five per cent. can be reduced by one-half, then a total of no less than 10,000,000 tons can be saved. This represents a value of probably not far short of $200,000,000, or the same furnaces now engaged in what are practically remelting operations can be turned on to producing a further supply of steel for other purposes. Besides, there is the considerable saving effected of avoiding loss of oxidation, both in the melting and subsequent reheating furnaces—this in itself a great waste which is absolutely unnecessary.

By the use of the system now described not only are the qualities of the ingot greatly improved, but these at once make themselves felt in the superior product obtained when rolled or forged. When producing billets from ingots cast by the ordinary method to be used for projectiles,—that is, from ingots not cast by the sound method,—the working results in actual practice show no less than 6.2 per cent. of waster projectiles owing and due to the defects in the material arising from those which originally existed in the ingots. Upon exactly the same nature of products,—that is, projectiles, from ingots made by the sound steel method, including the feeding arrangement,—the wasters were reduced to the low figure of only *1.4 per cent.* Wasters owing to seams, roaks, and other causes were therefore reduced from 6.2 to 1.4 per cent., a reduction of no less than 4.8 per cent.; thus on every 10,000 projectiles obtained from ordinary ingots there would be a saving of no less than 480 projectiles.

In a large daily output of steel it will be understood that this system enables a very important saving to be obtained, not only in reducing the discard and avoiding loss of material, but, as will be seen from the foregoing facts, by shortening the time of output.

In addition, there is an enormous saving effected by the discard being reduced from forty per cent., which is insisted upon for ordinary ingots, to only fifteen per cent. from ingots made under the author's system. In other words, while projectiles produced from ingots made in the ordinary way require, say, 1000 tons of ingots, under the author's system only 750 tons of ingots are required to produce the same number of projectiles. This represents a saving of no less than 250 tons of ingots.

TABLE 4.

Table Showing the Time Occupied in Tapping and Casting Twelve Heats from a Fifteen-ton Open-hearth Furnace (Acid) into Ingots Made by the Hadfield System of Making Sound Steel.

Size of ingots, 11 inches.

Heat No.	Time occupied opening tap-hole		Time running into ladle		Time occupied from dropping spout to casting first ingot	Time occupied from commencing to cast first ingot to finish of cast		Number of ingots cast	Total weight of ingots cast	Total weight of ingots cast
	Min.	*Sec.*	*Min.*	*Sec.*	*Sec.*	*Min.*	*Sec.*		*Tons*	*Pounds*
S. 1476 A	4	0	3	45	15	22	10	21	16	36,000
S. 1477 A	4	30	4	0	12	22	0	22	17¼	38,500
S. 1478 A	4	15	3	50	12	22	58	21	16	39,900
S. 1479 A	4	0	4	5	12	22	18	21	16¼	36,300
S. 1480 A	4	10	3	48	12	22	14	21	16	35,900
S. 1481 A	4	0	4	10	11	24	3	22	16¾	37,800
S. 124 B	4	0	4	15	12	23	0	21	16¼	36,200
S. 125 B	5	10	4	8	11	23	8	21	16¾	37,700
S. 126 B	4	8	3	50	12	22	50	21	16¼	36,200
S. 127 B	4	0	3	55	12	22	10	21	16	36,000
S. 128 B	4	30	4	0	12	22	12	21	16¼	36,200
S. 129 B	4	10	3	46	12	22	55	22	16¾	37,700
Average..	4	40	3	56	12	22	30	21	16½	36,600

1. Each of the sand heads was dried separately by means of hot coke taken from ladle previously used for ladle heating.

2. Size of nozzle in casting ladle, 1¼ inches diameter.

3. Each of these 11-inch ingots weighs ¾ ton (1700 pounds).

4. One sand head lasts at least six heats; that is, will make 4½ tons (10,000 pounds) of steel before being worn out.

5. One youth makes 21 sand heads in seven hours. It will be seen, therefore, that one youth can make in seven hours sand heads equivalent to 126 ingots, or, say, 20 per hour.

6. By machine-moulding these sand heads the time required for their production could probably be reduced to one-fifth that now occupied.

7. It is specially important to mention that the ingots should not be run too fast. This, of course, depends not only on the size of the nozzle, but how the stopper is lifted or handled.

The use of this system would not only give superior rails, but enable the quantity of what are known as "first class" rails to be increased, and those termed "second class" to be reduced to practically *nil*.

Table 4 shows the full particulars of twelve fifteen-ton heats of open-hearth steel cast into ingots made by the Hadfield system. The steel in question contained 0.40 per cent. carbon; otherwise it was the same quality as that referred to as used for rails. Plate IV shows the casting operation, and Plate V after the casting had taken place. From these photographs it will be seen there is nothing complicated about the application of this system; in fact, the author has personally seen heats cast in which, if it had not been known the system was being used, the differences in time of handling as compared with ordinary steel would not have been detected. Beyond the preparation of the heads, the cost of which has been reduced to some twenty to thirty cents per ton, and assistance in the casting pit, it would be difficult to determine ordinary heats were not being poured. In other words, one of the great advantages of the system is that there is nothing complicated or expensive about either applying or carrying it into operation.

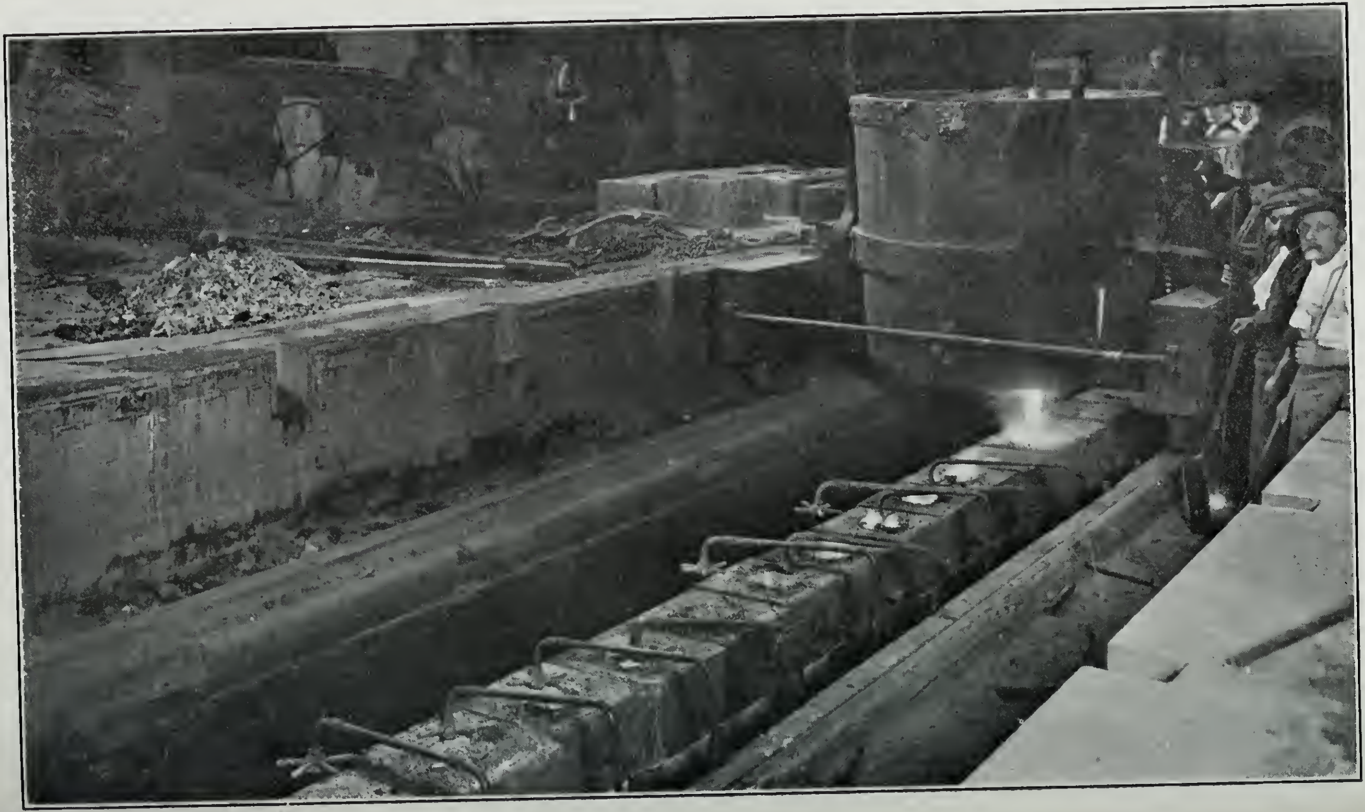
Table 4 gives the actual time occupied in casting, also data referring to the time of making and drying the sand heads. From the figures given it will be seen this operation presents no special features.

No doubt the preparation of the sand tops for a large output could be carried out by machine moulding, when their cost would be reduced to only a few cents per ton.

The sand heads are made to serve from four to eight heats, the only attention required being some slight patching up. The general cost of applying the system on a large scale would probably not be more than about twenty-five to thirty-five cents per ton. Moreover, this is recovered many times over by the much better quality and greater weight of steel obtained.

It may be added that the time required for casting a heat of ingots as compared with those made in the ordinary manner is about the same. The only labor necessary is one teamer and two ingot pit men. The total time occupied in a fifteen-ton heat the author recently saw cast was only about eighteen minutes. The

PLATE IV.



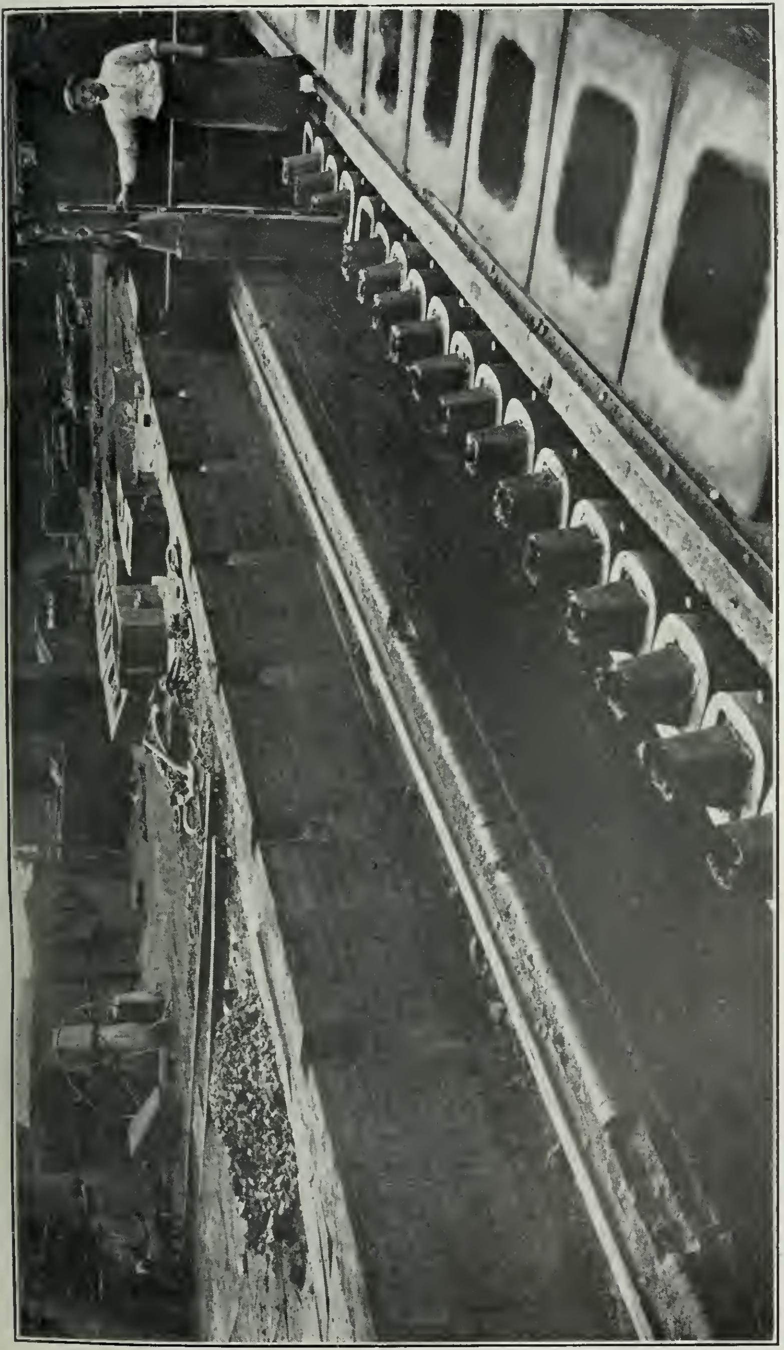


PLATE V.

regularity and uniformity of quality of such ingots are remarkable.

About 70,000 tons of ingots have been produced by this system. The remarkable soundness and cleanness of the steel so obtained have been invaluable in the production of projectile and other work.

To show how important the solution of the problem of sound steel is in America, the following statement has been officially made regarding the serious breakages met with on American railways:

> "Broken rails have caused 2762 accidents during that period (twelve years), resulting in death to 175 persons, injury to 6000, and property damage aggregating $3,237,792; on one railway alone there were 2760 rail failures during the months of November and December, 1911, and January, 1912; the number of rail failures which occur on railroads of the United States is constantly increasing."

There is no need, therefore, to offer any excuse for once more emphasizing how important it is that a thorough test should be given to methods which offer the production of sound steel for rails and other purposes.

The author takes this opportunity of offering his most cordial thanks to the Hon. W. C. Redfield, U. S. Secretary of Commerce, for the interest he has shown and for the assistance he has so kindly rendered on several occasions in granting facilities for carrying out important tests in this matter of sound steel; in fact, the particular lot of ingots described in this paper owes its origin to his desire that tests on rails made from sound ingots should be carried out on a large and practical scale. This friendly help will surely bring about improvements in practice which will add to the safety of the American travelling public. If more such friendly assistance were shown by the official heads of government departments in other countries, much quicker and greater advances in the practical application of science and industry, with consequent advantage to the public generally, would be found to follow.

A STUDY OF SOME CURIOUS PAINTING PHENOMENA.*

BY

HENRY A. GARDNER,
Assistant Director, The Institute of Industrial Research, Washington, D. C.
Member of the Institute.

Mildew and Its Prevention.

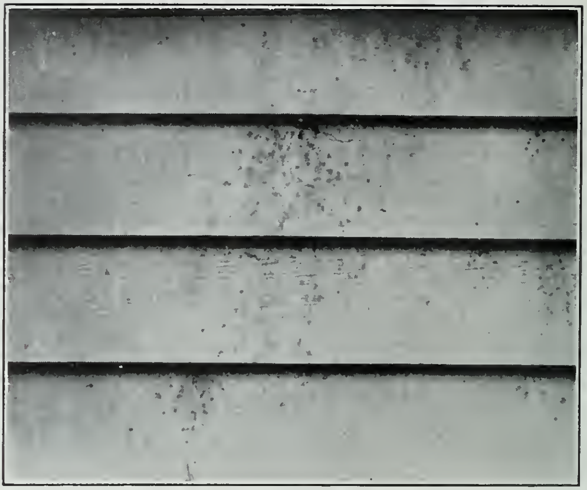
Upon a recent trip to New Orleans the writer's attention was called to several structures, the beauty of which was marred by fungous growths which were referred to by the painters as mildew. The condition was not universal, but appeared to prevail upon certain types of paint. Upon such paints it was found to be most severe in the sections which were shaded by trees or in partially-sheltered nooks where dampness would be maintained for a considerable period of time. If a window shutter had remained fastened back against the side of a dwelling for a month or so, the covered surface, upon inspection, would be found several shades darker than the rest of the house, many dark mildew spots being exhibited. The under sides of veranda roofs, as well as porch columns, also suffered severely in the same respect. It was quite apparent that the paint had in such instances remained soft or become softened by the action of moisture, thus presenting a surface to which adhered insects, cobwebs, and various organic substances carried by the wind. Since many of the streets of the city contained dust which may have originally been part of canal or river bottoms, it is quite apparent that much decayed animal or vegetable matter could be entrained by soft paint, thus supplying the spores responsible for fungous growths. Structures painted for several years with yellow paint seemed especially subject to fungus. It was found that the custom at one time was to use a colonial yellow for the body of houses, this paint having been prepared from carbonate of lead, using ochre as a tinting material. Recent experiments [1] have shown

---

* Communicated by the Author.

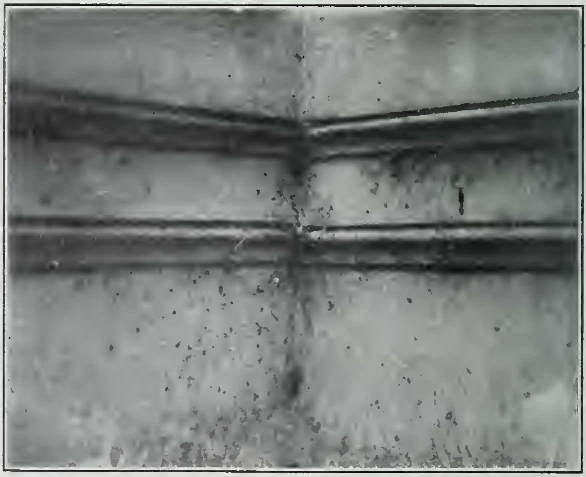
[1] Report of Sub-Committee X on Inspection of White Paint Test Fence at Washington, D. C., *Proc. A. S. T. M.*, vol. xiii, part i, pp. 287–311.

FIG. I.



Section of dwelling showing growth of "mildew."

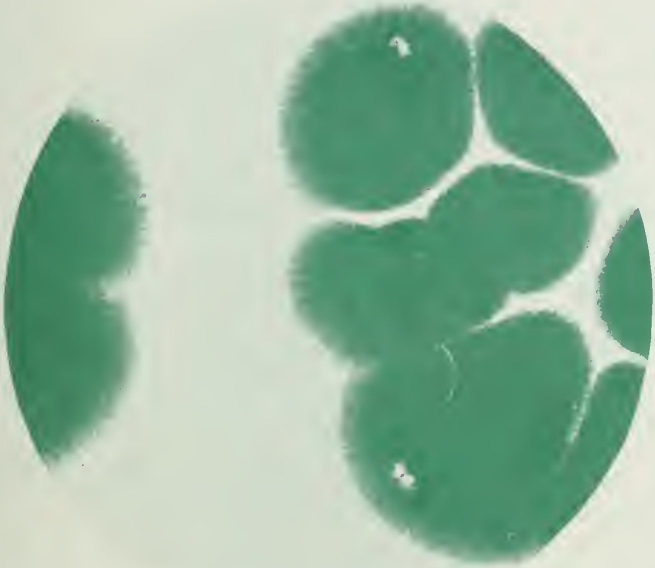
FIG. II.



Appearance of painted surface marred by fungous growth.

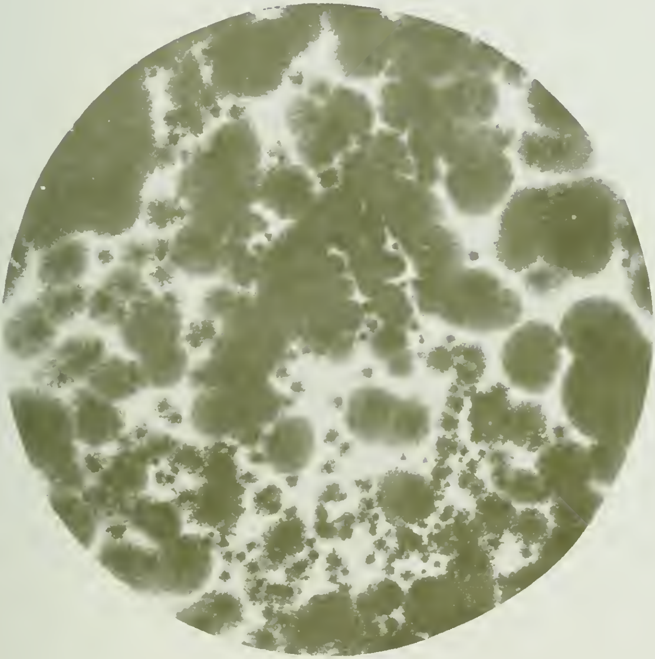
that lead paints mixed with inert or silicious pigments never dry properly and are subject to great darkening, caused by the retention of dust particles.

Fig. III.



Species of green Penicillium obtained from mildew on painted surface

FIG. IV.



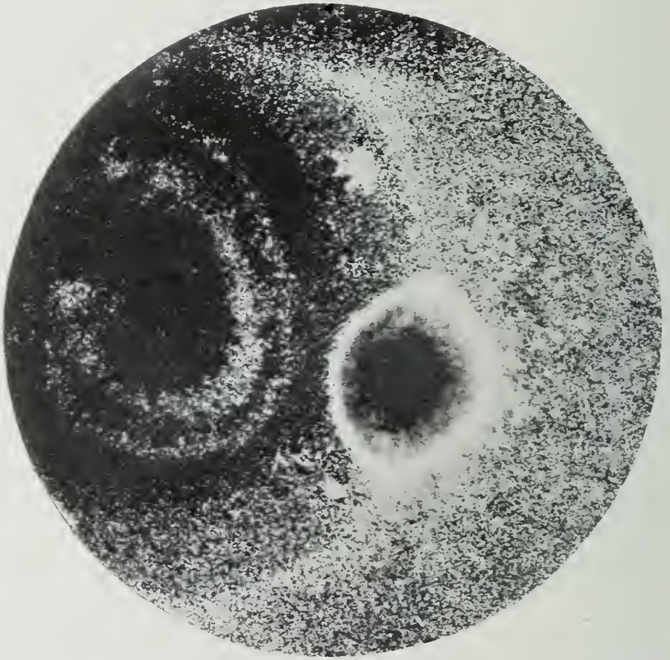
Species of Penicillium (olive green). (See text.)

During the inspection trip sections of painted surfaces showing marked formation of "mildew" were collected on lead-coated structures at Hearstville Levee, Carrollton, St. Charles Avenue, Bayou St. John, and other outlying points of the city. In some instances the mildewed surfaces were lightly scraped with a clean knife, the darkened scrapings being collected in a special envelope. Small pieces of wood with the fungus intact were also removed. For the purpose of examining these specimens, it was thought advisable to prepare a culture medium which would exert an inhibitory action upon ordinary bacteria which might be present upon the specimens but which would allow the rapid propagation of the fungous spores. Since cypress is one of the most important woods used for construction purposes, especially in the South, a cypress decoction was decided upon. This was prepared in the following manner, from a section of cypress wood obtained in New Orleans: Fifty grammes of finely-divided wood shavings were boiled in a half litre of distilled water. The decoction was filtered and 1½ per cent. by weight of thread agar was added. After steaming to obtain solution, the mass was filtered, tubed, and sterilized at 120° C. for fifteen minutes.

The infected paint specimens were embedded in the melted special agar placed in Petri dishes. The spores scraped from some of the infected areas were dusted upon the surface of set agar in similar dishes. These were placed in an incubator arranged with an electric thermostat set at 37° C. At the end of periods ranging from twenty-four to ninety-six hours marked growths developed on every plate. The moulds grown in this manner were of mixed types. The various kinds of fungi were isolated, and pure cultures were grown on agar in test-tubes, subsequently plating out the different species in Petri dishes. Some of these are shown in Figs. III to VI. The colors shown by the halftones are not exactly representative. Figs. VII to IX show their appearance under the microscope. Since the staining of fungi is a very difficult operation, some trouble was experienced in preparing slides for examination and photomicrographic record. It is felt, however, that those shown are fairly representative of some of the various species grown.

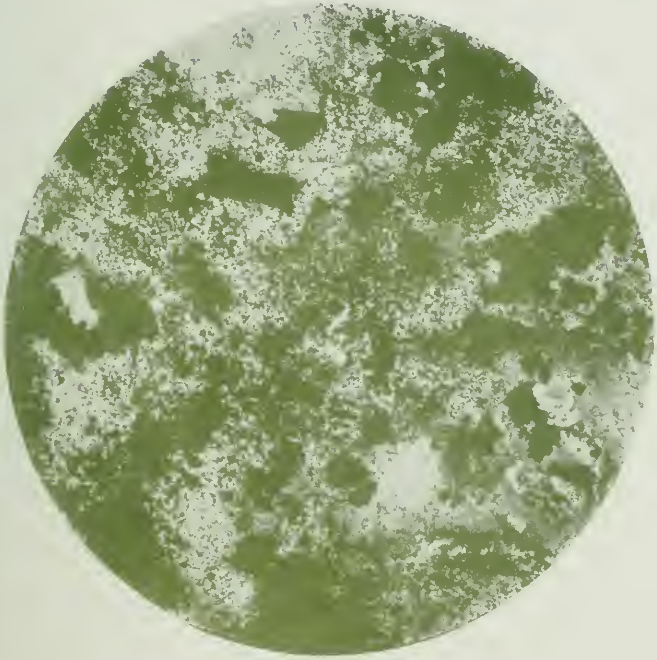
The two principal types of fungi which were developed from the mildewed surfaces were shown to be species of Aspergillus and Penicillium. In order to determine the relative resistance of these fungi, small sections of the specimens on agar were placed on painted boards which were kept in a chamber at a temperature favorable to their growth. In this test the black Aspergillus present proved most hardy, the others seeming dormant unless kept constantly moistened. In one test the black mould in a week's period exerted a most destructive effect upon a board coated with white lead in oil. Apparently the oil served as a most favorable medium for its development, thus playing one of the leading rôles in the reactions which resulted in the destruction of the paint and exposure of the wood. This action is recorded in Fig. X. The development of the fungi in every instance was much more rapid upon paint coatings which were soft and subject to retention of moisture. Paints which presented a firm, hard, moisture shedding surface resisted the fungi and prevented germination of the

FIG. V.



Species of Aspergillus (black) with spot of Penicillium (green) in centre. The effect of this fungus on painted surfaces is shown in Fig. X.

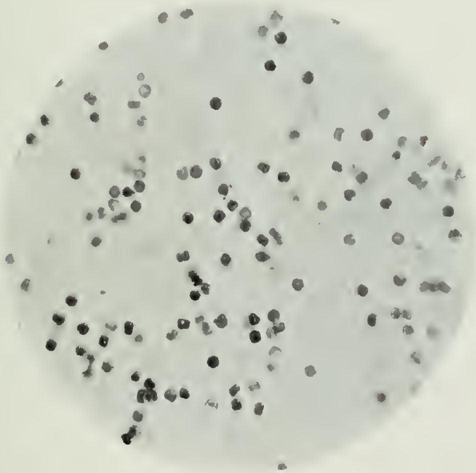
FIG. VI.



Species of green Penicillium that has developed yellow pigmentation in media.
(Yellow undercolor not shown in plate.)

spores. The board tests were then duplicated by floating the painted specimens inoculated with fungi upon the surface of water contained in a tank. The same comparative results were obtained. The paints which dried with a soft, tacky film were prepared from white lead. Those which dried to a hard, resistant film were composite paints containing white lead and zinc oxide. From twenty-five to fifty per cent. of the latter pigment was used to produce a resistant film. The oil used in all paints was linseed oil, to which was added five per cent. of liquid drier. Although it is possible that the absence of "smuts" on paints containing zinc oxide may be due to the formation in the paint film of a zinc salt which acts as a powerful fungicide, the writer is inclined to believe that the real value of the zinc is to be ascribed to its film-hardening characteristics. The addition of turpentine is also to be advised, since more rapid oxidation and firmer films are obtained.

FIG. VII.



Spores of the green Penicillium. × 1400.

It is customary for the lumber mills in some sections of the South to float the timber in adjacent ponds previous to sawing. These ponds sometimes contain dirty water filled with decayed vegetable matter and covered with colored scum. It is possible that various substances favorable to fungous growths are thus soaked up by the wood. When cut, used as siding, and painted, these substances may be leached out on some occasions. It is possible that this effect would be prevented by treating new lumber with a coat of zinc chloride solution previous to painting. The writer's tests indicate the high fungicidal value of such treatment. It is likely, however, that the use of hard-drying, dust-resisting paints would prevent the growth of fungi which might be present on the wood used. Before leaving the subject of mildew, it is of interest to quote from the findings of G. Massee,[2] who records a peculiar pink-colored fungi growing on white lead paint in a conservatory:

> "*A New Paint-Destroying Fungus.*
>
> (PHOMA PIGMENTIVORA, MASSEE.)"
>
> "Among the most remarkable of fungi is one that elects to grow on fresh paint. It flourishes in the greatest profusion in hot-houses, its development being apparently favored by a high temperature and constant humidity, as it is but rarely observed on paint elsewhere. About a month or two after a hot-house has been painted, more especially if white paint has been used, numerous small, pale rose-colored specks appear on the paint; these specks gradually increase in size and change to a purple, or sometimes dark red, color, suggesting the idea of blood having been sprinkled over the paint. In course of time the discolored areas extend considerably and form broadly-effused patches several inches across. About a week after the colored patches are fully developed, their surface becomes studded with minute, blackish-red warts. Each wart is a fungous fruit, containing myriads of very minute spores, which in due course are dispersed and start new points of infection.
>
> "When the spores of the fungus are sown on a streak of wet white paint, a faint roseate tint appears in about a week's time, and within three weeks fruit is produced in abundance, and the deep purple characteristic blotches are well developed. Spores sown on a thin

---

[2] Royal Botanic Gardens, Kew, *Bull. of Miscel. Information,* 1911, London.

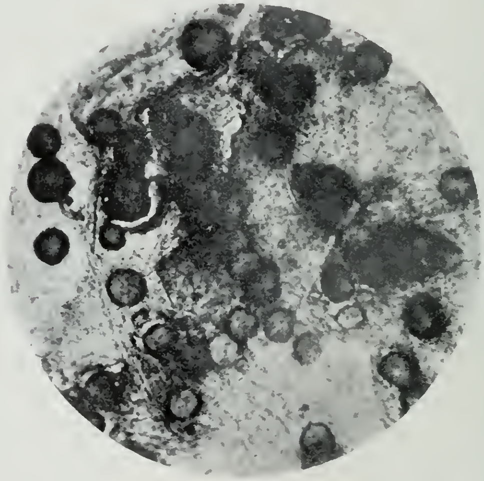
smear of pure linseed oil germinate as readily as in paint, but the mycelium remains colorless, and, so far, no fruit has been produced. The result is the same when the spores germinate in ordinary nutritive media or in water. No germination takes place when the spores are sown on a streak of pure white lead or carbonate of lead (pigment). Hence this substance alone is not a suitable medium for the growth of the fungus, although its presence is necessary to enable the plant to complete its normal course of development, and it is also the constituent from which the fungus produces as a by-product the purple-red coloring matter, which is collected in oily-looking drops within the cells of the mycelium, the cell-walls themselves remaining colorless. The red color suggests that the white carbonate of lead undergoes some chemical change induced by the presence of the fungus, resulting in the formation of red oxide of lead. This matter, however, requires careful investigation. The presence of two per cent. of carbolic acid in paint completely arrests the development of the fungus. The following is a technical description of the fungus:

" ' Phoma pigmentivora, Massee. Maculæ suborbiculares, determinatæ, læte rosaceæ vel rosaceo-purpureæ, 1–8 cm. diametro. Perithecia in maculis laxe gregaria vel confertiuscula, vix prominula, purpureoatra, subglobosa, contextu parenchymatico, ostiolo vix papillato donata, 125–150 u diametro. Sporulæ ellipsoideæ, hyalinæ, 4–6 x 2–2.5u.' "

Washing of Paint Caused by Inferior Oil.

That microörganisms may play an important rôle in the behavior of materials of painting is the conclusion of the writer, based upon recent investigations into the causes of certain painting defects which have been referred to by the painter as saponification or washing. This condition is generally indicated by the appearance of a white deposit at the base of porch columns and by the paint assuming a soap-like condition if rubbed. Although the instances of such actions are rare, an apparent epidemic has recently been shown to exist in one community. The writer has made an inspection of the structures where the trouble occurred, collecting samples of the washed paints for analysis. The investigation also included the analysis and examination of the materials used in the paint, including the oil that was mixed by hand with the paste paint. Almost invariably the oil used was found to contain considerable moisture. When a bottle containing the oil was shaken, large numbers of water bubbles would appear and the oil would form a cloudy emulsion. The oil also contained a large percentage of mucilaginous or albuminous matter which is commonly called "foots." In the pressing of flaxseed, the oil is filter-pressed. This, however, takes out only a portion of the suspended matter. After standing a short period of time, certain types of albuminous matter in solution in the oil begin to precipitate out, forming flocculent precipitates which are known as "foots." Improperly filtered oil, that is rushed to the consumer without proper clarification, always contains such impurities. Portions of the foots from the various samples of oil collected were placed upon sterile agar, and in a few days marked growths of a peculiar pink-colored mould were

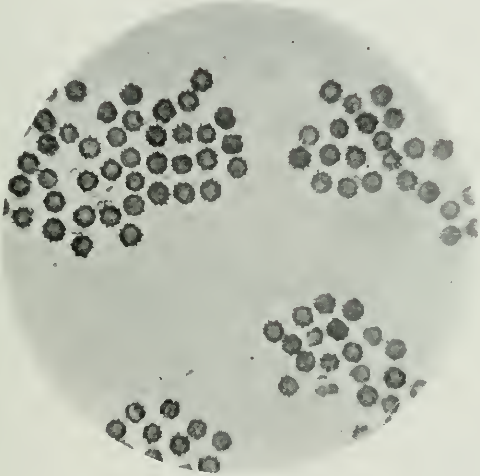
FIG. VIII.



Mycelium and sporangia of the black Aspergillus. × 110.

obtained (see Fig. XI). This mould was identified as a species of Fusarium by V. K. Charles, Assistant Mycologist, Bureau of Plant Industry. Portions of this mould placed upon oil seemed to have a marked effect in changing the constants of the oil, free acid being produced. This result gave a clue to the causes of the washing of paint in which the infected oil was used, and indicated the nature of the intricate reactions which would be occasioned in the drying paint films. The enzymes and microörganisms in the foots apparently exert a fat-splitting action, the oil being broken up into glycerine and fatty acids, causing the formation of soap-like products which are acted upon by moisture. The glycerine formed in the film is, of course, non-drying in nature, serving to keep the paint soft and tacky, in which condition it readily attracts moisture from the air. The moisture thus absorbed by the film emulsifies with the soft paint, some of which washes off, depositing upon any convenient surface.

FIG. IX.

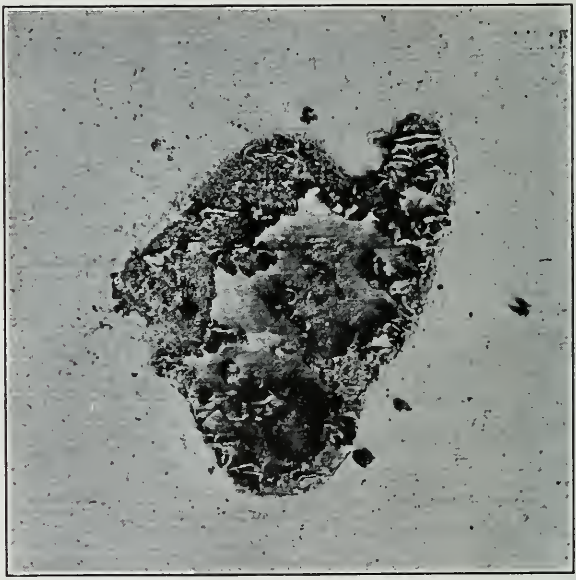


Spores of the black Aspergillus. × 1400.

The writer has found that there is no selective action in the washing of the paints; in other words, there is no greater tendency for a lead paint to wash than a zinc paint. This was confirmed by the analysis of the washings piled up at the base of some hollow fluted porch columns at various residences. Some of the paints applied were made of lead and some of lead and zinc pigments. In every instance lead was found present, zinc being detected in the washings from some zinc-containing paints.

Attention has been brought to the fact that the washing of paint is not of uniform occurrence. It may be noticed upon the porch columns but not upon the body and trim of a house, or it may be noted only upon certain sections of the main structure.

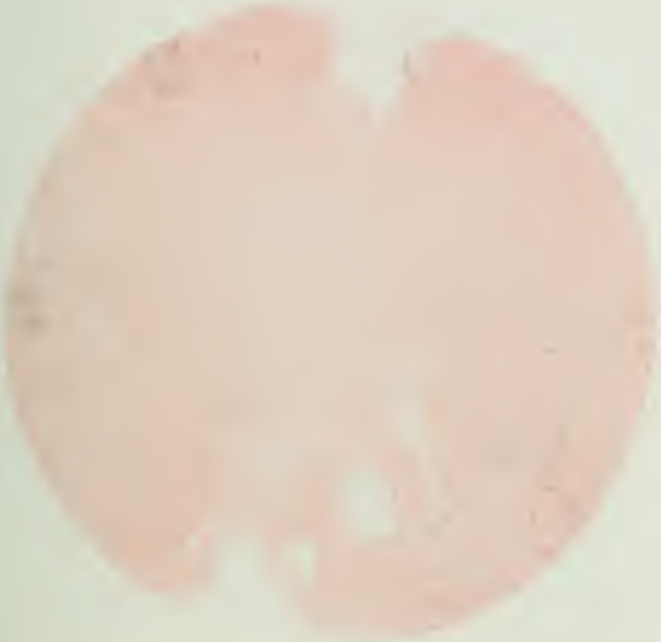
FIG. X.



Effect of black fungi upon soft drying paint.

The writer has observed that in most instances where washing is shown it is generally upon a hollow column or surface, the back of which may hold moisture. It is likely that the moisture stored up in certain places is responsible for starting the complicated reactions which have been previously referred to. It is also possible that the painter, when making up various batches of paint, may use in one batch that portion of the oil which contains the largest quantity of foots and moisture. The section upon which this batch of paint is used would, of course, show the

FIG. XI.



Pink mould growing from "foots" of infected oil.

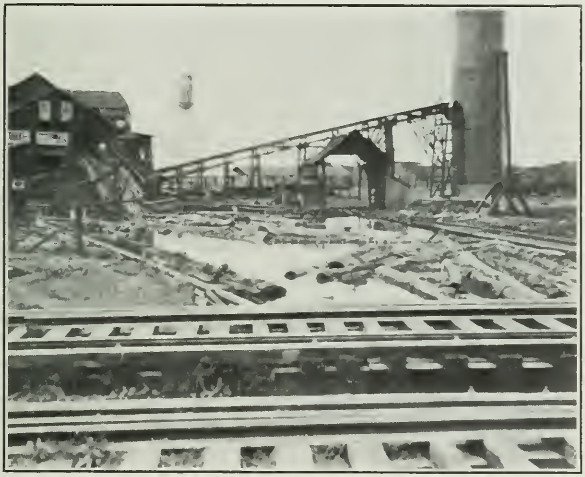
(Species of Fusarium.)

greatest amount of washing. That such types of washing are periodical could be explained by the fact that infected seed occurs in quantity only in such years as the flax crop is poor. In the writer's opinion, the prevention of such trouble lies in the use of a well-filtered, perfectly-clarified, moisture-free oil.

"Rusting" or Brown Spotting.

Another painting defect, the cause of which may be traced in some instances to the action of microörganisms or their products, is the so-called "rusting" or brown spotting of paints. This condition is generally noticed upon the ceilings of porches, small brown spots about a quarter of an inch in diameter appearing through the paint film like resin exudations. These spots have an astringent acid taste. This condition, moreover, is generally found upon jobs where the type of washing of paint previously referred to has been recorded, thus indicating that the trouble might be of similar origin. Several of these small, brown-colored spots which appeared upon painted surfaces were recently collected and examined. In some instances these drops were shown by chemical analysis to contain resinous ingredients,

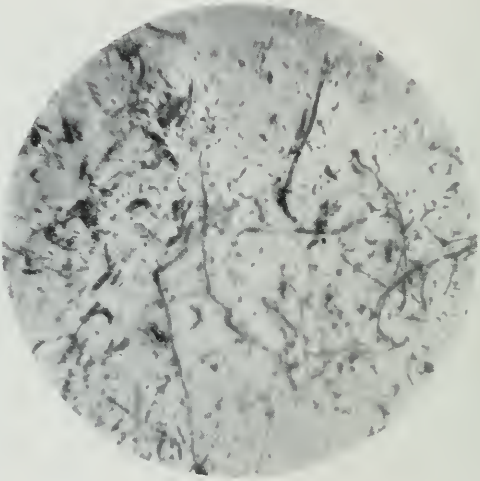
FIG. XII.



Lumber mill showing log pond. (See text.)

and in other instances metallic substances in combination with organic products. They are generally very soluble in water, yielding rather thick, viscous solutions upon boiling and filtration. When the paint is made of lead, organic salts of lead are found in the solution. If zinc is present in the paint, zinc salts may also be found by analysis. As a result of the investigation, the writer is firmly convinced that the formation of these drops may be traced to two distinct causes. In some instances the soluble matter contained in the wood may be brought to the surface, exuding at certain places in the paint film and drying up to small, round globules. In certain types of wood there are exceptionally large amounts of soluble constituents which may appear, especially in damp weather and upon surfaces which are not exposed to the sun. Such water-soluble substances apparently have a solvent effect upon the lead and zinc contained in a paint, the compounds formed being deposited upon the surface of the paint in the form of globules. This condition, however, would occur only upon new wood. When wood has been painted for three or four years, it has weathered to such an extent that the water-soluble materials are pretty well leached out. It has

FIG. XIII.



Mycelium and spores of the pink mould. × 1400.

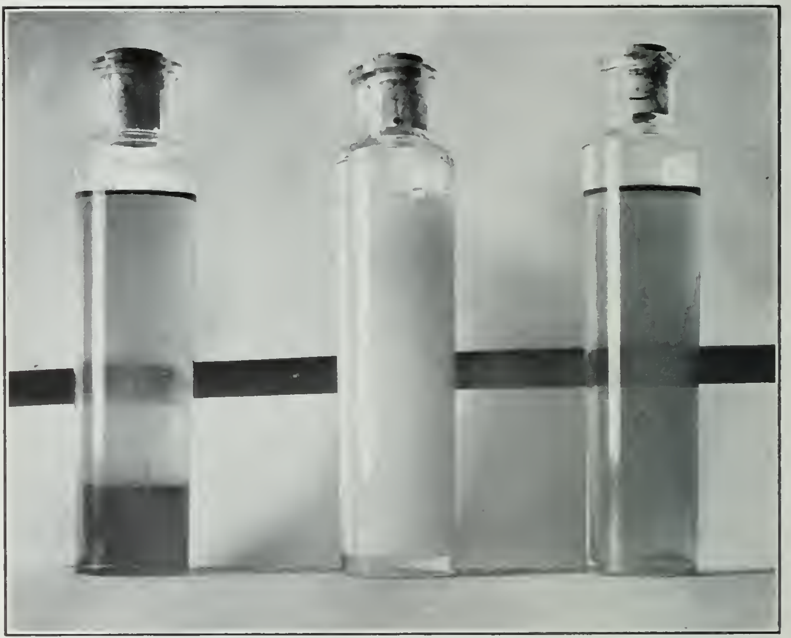
been found, however, that brown spotting occurs most often upon repainting jobs, especially when the oil used in the paint has been of the type examined by the writer, containing moisture and foots of an infected nature. In such cases the hydrolyzing action of the enzymes, which takes place when such oil is used, apparently increases the tendency of the oil to break up into various fatty acids, including formic acid. This has a solvent effect upon the lead and zinc pigments, producing lead and zinc formates which are water-soluble and possessed of an astringent taste. It is therefore likely that such water-soluble metallic compounds, when produced, come as the result of reactions within the oil itself in many instances, and would again indicate the necessity of using properly-clarified oil. The writer

FIG. XIV.

Growth of fungi upon porch column.

has previously pointed out that proper weathering of new wood before painting will largely do away with the type of spotting that comes from the water-soluble constituents of such wood.

FIG. XV.



Three samples of linseed oil. Black line in back of bottles shows relative clarity. Oil in middle bottle contains considerable moisture and "foots." Oil in end bottle contains a large amount of infected "foots" deposited at bottom.

It is apparent, however, that the selection of satisfactory oil is an even more important consideration, especially upon repainting work.

Immunization of Oils.

Assuming that some types of oil[3] may even be responsible for defects developing in paints while in storage and previous to use, the question of immunization is one worthy of consideration. Although the writer has previously shown that sterilization of the oil is possible by the application of heat, this procedure may not be feasible in many instances. The same effect, however, may often be produced in the paint mill under ordinary manufacturing processes. It is well known that considerable heat is developed when mixtures of oil and pigments are run through buhrstone mills, the temperature of the paint depending upon the rate of grinding and set of the plates. Temperatures up to 240° F. have even been recorded, and this is more than sufficient for sterilization. It is probable that many oils have thus been rendered harmless, whereas they might have caused trouble had they been mixed cold with hand paddles. Moreover, the hot paste paint as it issues from a mill is in a condensed form, unobtainable by hand stirring. The writer has recently made a study of the chemical phenomena which may result from the storage of such paints in their warm condition. In one instance the hot paste was immediately thinned and canned. In another instance the paste was allowed to cool before thinning and canning. In the latter case the paint proved to be in the most satisfactory condition after storage. When the hot paste is immediately canned, the continued warmth of the product is apt to set up slight hardening with certain pigments. It is probable, however, that the use of a water-cooled spout at the point of exit from the mill plates would sufficiently cool the issuing paste so that storage before canning would not be necessary.

---

[3] "Changes Occurring in Oils and Paste Paints, Due to Autohydrolysis of the Glycerides," by H. A. Gardner, JOURNAL OF THE FRANKLIN INSTITUTE, May, 1914.

Conclusion: From the previous considerations it is apparent that many painting defects may be prevented through the use of paints of the composite class, based upon white lead pigments but containing sufficient zinc oxide to present a firm, hard film.

When paste paints are thinned by the painter, only clarified, well-settled, moisture-free linseed oil should be used.

The writer wishes to acknowledge the valuable assistance of T. M. Rector in the experimental work.

Physical Properties of Cobalt. H. T. KALMUS and C. HARPER. (*J. Ind. Eng. Chem.*, vii, 6.)—The cobalt examined was reduced from the oxide. The pure metal, containing 99.1 to 99.9 per cent. cobalt, resembles nickel in appearance, but when electro-deposited and polished has a slightly bluish cast. The specific gravity referred to water at 4° C. is 8.7918 at 17° C. for the unannealed metal, 8.8105 at 14°.5 C. after annealing, and 8.9253 at 16°.5 C. after swaging. The Brinell hardness determined in a standard Olsen machine, with a load of 3500 pounds, was about 124 for cobalt cast in an iron mould, that of nickel cast under similar conditions being about 83 and of cast-iron about 102. The presence of 0.06 to 0.37 per cent. carbon had less effect on the hardness of cobalt than slight variations in heat treatment. If the melting-point of nickel be taken as 1452° C., pure cobalt melts at 1478° C. ± 1.1° C. It has a tensile strength of about 34,400 pounds and a compressive strength of about 122,000 pounds per square inch as cast, the corresponding figures after annealing being 36,980 and 117,200 pounds per square inch respectively. Cast cobalt containing 0.06 to 0.3 per cent. carbon has a tensile strength of about 61,000 pounds, and a compressive strength of about 175,000 pounds per square inch. Both the tensile and compressive strengths are greater than those of pure iron or nickel cast and tested under similar conditions. The reduction of area and elongation are low for pure cobalt, but rise to above 20 per cent. in the case of "commercial" cobalt, 96.5 to 99.6 per cent. Co, containing carbon and other impurities. Pure cast cobalt can be machined in a lathe and, if the casting be cooled under high pressure, can subsequently be rolled or swaged at 500° to 600° C. Commercial cobalt is easily machined and can be rolled or swaged at red-heat without any special preliminary treatment. The specific electrical resistance of cobalt wire of high purity is 89.64×10^{-7} ohms per cubic centimetre, and is largely influenced by the presence of occluded gas, being increased by annealing in an inert gas at low temperatures and diminished by annealing *in vacuo*. The electrical resistance of commercial cobalt is 231×10^{-7} to 103×10^{-7} ohms per cubic centimetre, and is greatly reduced by annealing *in vacuo*. The specific heat of pure cobalt between 0° and 890° C. is given by the formula:— $0.1058 + 0.0000457t + 0.00000066t^2$. The paper is illustrated by eleven photomicrographs.

Long Reinforced Concrete Bridges. ANON. (*Sci. Amer. Supple.*, lxxix, No. 2041, 109.)—Reinforced concrete is so rapidly coming into general use that figures relating to bridges of this construction are of unusual interest. The Walnut Lane bridge has a span of 233 feet; at Grafton, New Zealand, there is a bridge with a span of 320 feet; over the Tiber, at Rome, 328 feet; at Largweiz, Switzerland, 330 feet; and the proposed bridge over Spuyten Duyvil Creek, New York, 703 feet.

THE IONIZING POTENTIAL OF AN X-RAY TUBE.*

BY

E. C. DREW, M.S.,

Fellow in Physics, University of Pennsylvania.

The following is a brief account of a research undertaken by the writer to obtain further information regarding the ionizing potential of an X-ray tube.

For a long time various German and American authorities have been asserting that the ionization potential of a Röntgen tube was higher than the running potential; or, in other words, that it takes a much higher voltage to break down the gap between the electrodes, so to speak, and start the ionizing currents flowing than it does to maintain this flow, once started. As to the real basis for this belief very little information can be found. It seems, in many respects, to be another case of "Newton said it is so, and so it must be."

To quote from several sources, we find that "Once the path is rendered conducting, the flow through the tube is accomplished more easily. The resistance of the tube falls off and the drop across the tube decreases. A current now flows through the tube on account of the diminished resistance, until finally the voltage has decreased so much that the flow stops" (Dessauer [1]). "The flow of current—after the breaking down of the tube—does not cease even if the voltage drops considerably below the break-down potential. If one excites a Röntgen tube with an alternating current, the flow of current does not start at the same instant that the potential passes through zero value, but delays in starting until the attainment of the break-down potential. The current starts as soon as this point is reached, and also continues after the voltage has fallen below it" (Fürstenau [2]). "Finally, the current falls again rather suddenly and apparently at the same time as the potential until the slowly-decreasing voltage of the transformer is no longer sufficient to pierce the tube vacuum. The value of this potential, however, is considerably less than that which was necessary for the original breaking down of the tube resistance. For the resistance of the tube vacuum always falls to a quite noticeable extent during the stream passage, in consequence of the ionizing action of the current itself" (Albers-Shönberg[3]). "In the case of the X-ray tube, as the break-down voltage is higher than the running voltage, it is doubtful what precisely either voltmeter or spark gap affords" (Kaye[4]). "In the ordinary tube (gas tube) the break-down voltage is much higher than the running voltage" (Coolidge[5]). "No focus tube has so far been found which will maintain a greater unfluctuating voltage than 100,000 volts, although many tubes need a greater voltage than this to get them to light up" (Cabot[6]). Many other similar statements can be found in articles and works of recent date, but the above are sufficient to point out the prevailing impression among those who have contributed some of the most valuable information in the field of röntgenology.

---

* Communicated by Mr. H. Clyde Snook.

It was the opinion of the writer that an experimental investigation of the point would be interesting and might prove to be very much worth while. Although the work has not been carried to completion, it was thought desirable to publish the preliminary work, to which additions will be made in the near future.

In making a choice of methods, the sine wave form of the present type of high-tension machines generally used for tube excitation and the loop oscillograph seemed to lend themselves well to the work in view. A schematic diagram (Fig. 1), given herewith, shows the arrangement of the principal features of the apparatus.

The transformer and rectifying switch were of the Snook type, consisting of an inverted rotary directly connected to the mechanical switch. The oscillograph was of the General Electric type and contained three loops, carefully selected for sensitiveness and properly damped to just prevent overshooting at sudden changes of conditions. One of these loops (I_s) is placed directly in the secondary circuit between the high-tension terminals (T T') and in series with the tube and milliammeter. Its function, as suggested, is to register the wave form of the secondary current. In series with the primary of the transformer is inserted a short piece of nichrome wire which serves as a shunt to the loop (I_p). This shunt and loop together constitute the recording device for the primary current. A third loop (E_p) in series with a non-inductive resistance is placed directly across the primary winding alone. This indicates the curve form of the primary electromotive force and incidentally to a reduced scale (depending on the ratio of transformation) the potential across the secondary terminals at the same time.*

For purposes of calibration, a source of direct current may be applied through the control and primary of the transformer. This will produce a constant deflection in two of the loop systems (I_p and E_p), which can be shown directly on the film. By an auxiliary circuit of cells and resistance the third loop (I_s) may be similarly calibrated (see Figs. 1 and 7).

---

* That this is possible is apparent when we note that the reactance of the secondary circuit is practically negligible, there being only the self-induction and capacity of the tube, milliammeter, oscillograph loop, and straight connecting leads, with a ground connection between the tube and loop.

The ground connection is necessary for protection on account of insufficient insulation, and, in the opinion of the writer, is justifiable. Both Snook[7] and Duddell[8] used a ground in their work with the induction coil, and, although criticised by Wertheimer,[9] the latter's criticisms are not valid in the present instance. For:

1. The loops used have a free period of less than 1/5000 second, which would seem to be adequate when we consider that the speed of the rotary is only 30 revolutions per second. In the curves shown here the time taken for a half wave is 1/120 second.

2. The secondary potential is measured by an indirect method, which is not open to the objections raised in a direct method (viz., same current through the loop as through the main circuit).

3. The loops used are sufficiently sensitive for the currents involved.

4. To the writer's knowledge, no evidence has ever been given of errors introduced by making a point of zero potential in a closed circuit of this kind. At any rate, it is a question of doing this or something else perhaps equally objectionable.

Bown,[10] in a recent article on the wave form of currents in a Coolidge tube, adopted the scheme of inserting a small current transformer in the secondary circuit and in series with the tube. He claimed thereby an advantage of obtaining large-sized deflections for small-sized currents. Both Snook[11] and Salomonson,[12] by means of an oscillograph, have shown the oscillations which occur in the primary and secondary of a transformer or coil, and they explained them as functions of the capacity and self-induction of both circuits, together with the kind of a load on the secondary. The writer's experience with the oscillograph leads him to believe that the oscillations which follow the main impulses of the inductor in Bown's curves are probably due to the effects introduced by the use of the current transformer.

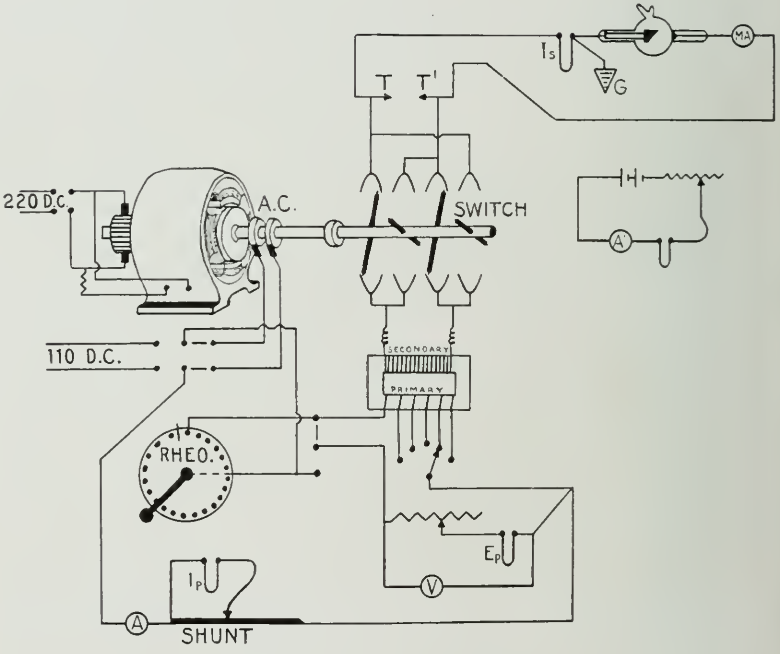
The tubes used were of standard commercial types, which may be divided into three classes:

1. The old type of gas tube, with the chemical regulator introducing a more or less complex gas.

2. The new hydrogen tube, with an osmosis regulator which admits only pure hydrogen.

3. The electron tube, which depends on a hot cathode to supply the electrons of the cathode stream.

FIG. 1.



Schematic diagram of apparatus.

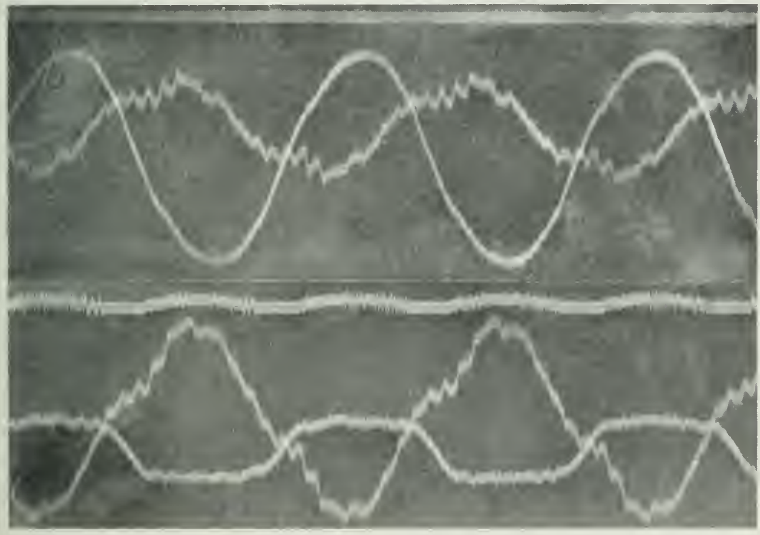
The hydrogen tube has been used to a far greater extent in the preliminary work because of its great flexibility, which enables the operator to control the vacuum in either direction, up or down.

Oscillograms were taken as indicated, some of which are discussed herewith.

If the secondary of the machine is left open-circuited and only the corona effect allowed between the terminals, the milliammeter will read practically zero and the primary electromotive force will be nearly sinusoidal in form. The primary current will be that necessary to produce the magnetization in the transformer iron, to charge the high-tension switch and secondary terminals electrostatically, and to furnish the current represented in the energy of the corona. This condition of affairs is shown in Fig. 2.

If we leave all the controls as above and insert an X-ray tube between the two terminals, the wave forms will be modified (see Fig. 3). The top curve is the current through the tube, a rectified sine wave in form. The current curve in the primary has changed its phase relation slightly, and the amplitude has been increased to correspond with the production of current in the secondary. The potential (either primary or secondary, as stated above) still starts from zero along the sine path, but as soon as the potential has risen to a value where the gas begins to ionize, it remains *practically constant* until the mechanical switch is opened. Question: *If, as is claimed by so many, the ionization potential is so very much greater than the running potential, why should there not be a high peak in this curve at the beginning of the half cycle?*

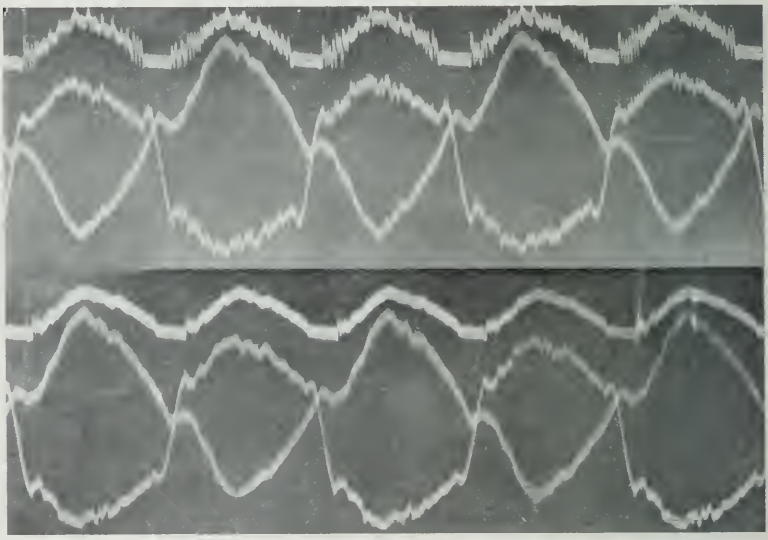
FIGS. 2 AND 3.



The conditions in Fig. 4 are similar to those in Fig. 3, except that the controls have been adjusted to allow more current to pass through the tube. The voltmeter reading in this case was 107 and the milliammeter reading was 32.

The small oscillations shown in the potential and secondary current curves are due to the air gaps at the ends of the revolving arms in the rectifying switch. To eliminate these and obtain smooth curves, small wire brushes were soldered on the ends of the arms. These made a rubbing contact with the metallic arcs of the switch and produced results shown in Fig. 5. Here the meter reading of the current through the tube was 40 milliampères. The integrated value of the volts drop across the tube was about 83,300 volts, with a maximum value about 20 per cent. greater. Both the current and potential curves are much smoother than in the preceding figures, but there are apparent differences in the separate half cycles and there are teeth at both the beginning and end of the flow of current. (The meaning of these teeth will be discussed at a later date.) However, even this condition of affairs was not stable, since the brushes were bent

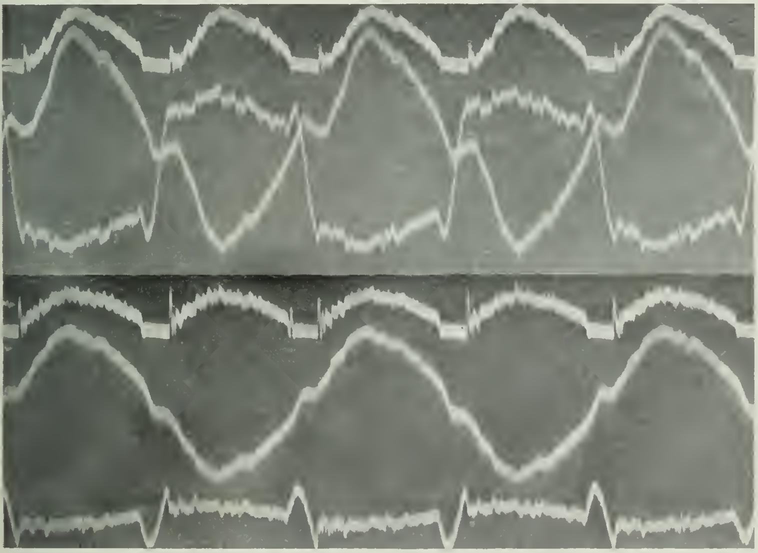
FIGS. 4 AND 5.



back by the centrifugal force, and in some cases either cut or broken off by contact with the sharp edge of the metallic arcs.

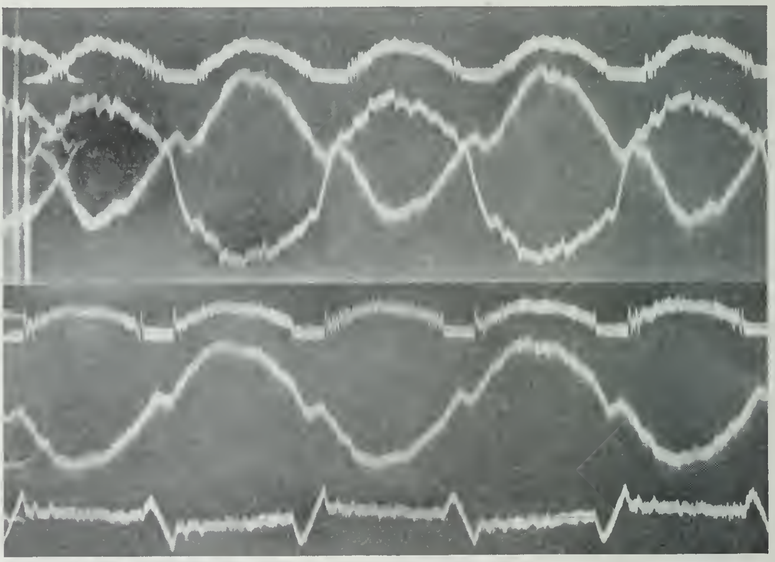
The next step was to make the air gaps a minimum without necessarily making absolute contact at all times. With this arrangement an exposure is made (Fig. *6a*) and the reading of the milliammeter very carefully noted. The oscillations are rather more prominent than in Fig. 5, but the wave forms were considered sufficiently good for first approximations. These curves portray what takes place in a hydrogen tube when backing up a 3½-inch parallel spark at 10 milliampères and carrying 36 milliampères at the instant of exposure. The upper curve is still the current passing through the tube. The ordinates of the potential curve, however, are not the potentials just sufficient to overcome the tube resistance, but include, in addition, the potential required to break down the little spark gaps in the mechanical switch.

FIGS. 6A AND 6B.



Now, having noted with care the number of milliampères flowing in the secondary, the secondary terminals were short-circuited directly through the oscillograph loop and milliammeter without the tube. The rheostat in the primary circuit was then adjusted to permit the same current to flow through the loop (36 milliampères) that was flowing through the loop and tube, but without changing any of the other controls at the oscillograph. The potential curve (bottom of Fig. 6*b*) this time represents only the drop across the spark-gap resistance, and it is thus a question of subtracting these ordinates from the corresponding ones above to obtain data which will enable us to plot a curve representing the potential just sufficient to keep the gas of the tube in an ionized condition. The current curves corresponding, although of slightly different shape, still have approximately the same integrated values as in Fig. 6*a*.

Figs. 7 a and 7 b.

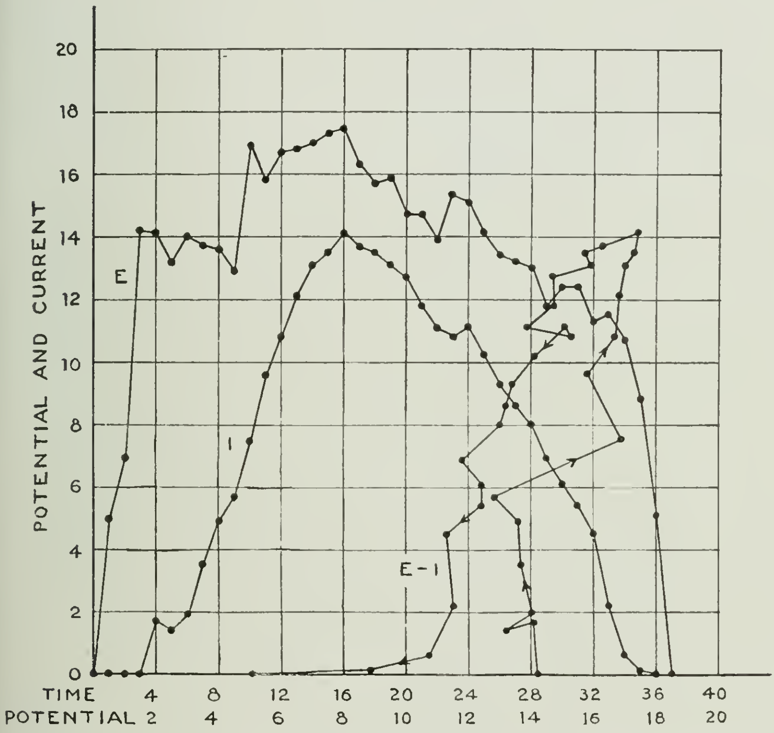


Figs. 7*a* and 7*b* are similar to Figs. 6*a* and 6*b*, except that a M. & W. tube (representative of the ordinary gas tube with chemical regulator) was used. This tube was backing up a 3¼-inch parallel spark at 5 milliampères and carried a current of 28 milliampères at the instant of exposure.

Fig. 8 contains the plots indicated in Fig. 6. Similarly, Fig. 9

shows the plotted curves for conditions indicated in Fig. 7. Also in Fig. 10 plots have been made for another hydrogen tube. The corresponding oscillograms are not reproduced, but the tube backed up a parallel spark of 3½ inches at 6 milliampères and carried 18 milliampères at the instant of exposure.

FIG. 8.



Hydrogen tube.

Curve E. Plotted potential against time.
Curve I. Plotted current against time.
Curve E–I. Plotted current against potential.
Scales: 10 divisions = 62 volts primary or 47,400 volts secondary.
10 divisions = 61 milliampères.
37 divisions = half cycle or $\frac{1}{120}$ second.
Maximum potential = 82,500 volts.
Maximum current = 86 milliampères.

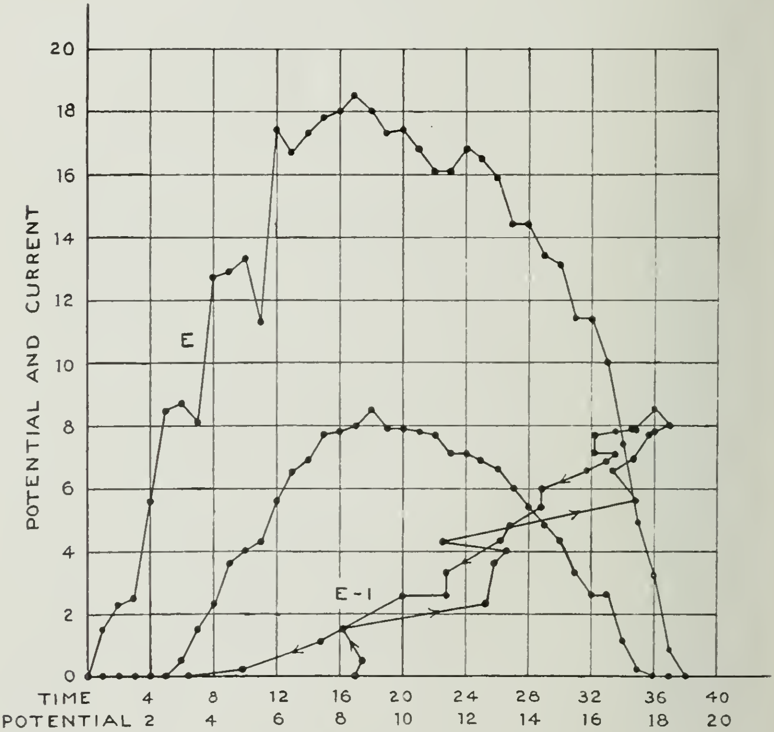
A glance at these curves and plots offers some interesting suggestions.

1. The oscillograms point to the X-ray tube as a constant potential device which tends to maintain a constant drop across it.

2. The approach of the potential-current plots of Figs. 8, 9,

and 10 to a half loop of the ordinary magnetic hysteresis cycle is notable, and is indicative of something different than a straight line law, like Ohm's law, in the tube circuit. In fact, it would seem that the law connecting the current and potential in a circuit of this kind is that of the ordinary saturation curve.

Fig. 9.



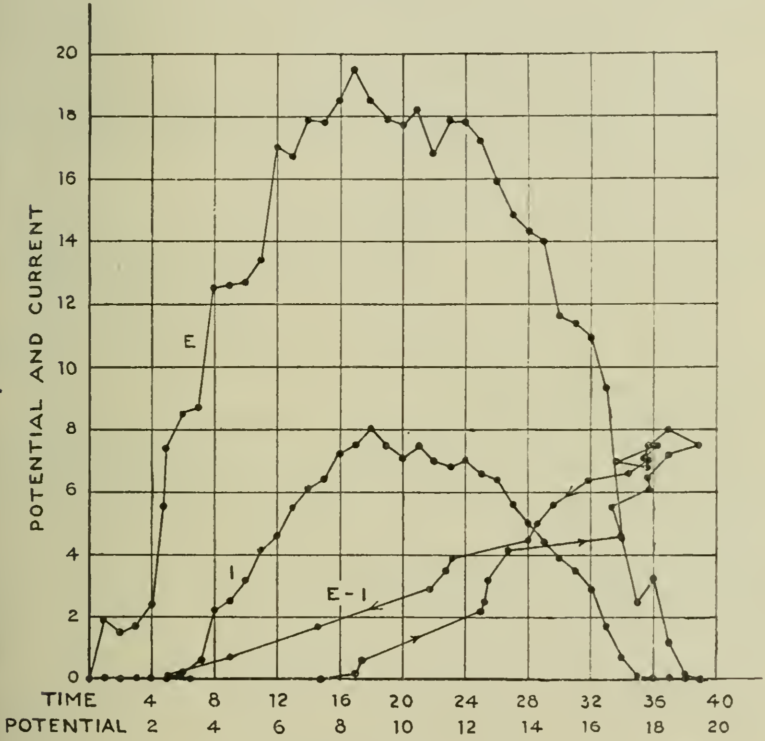
M. and W. tube.
Curve E. Plotted potential against time.
Curve I. Plotted current against time.
Curve E–I. Plotted current against potential.
Scales: 10 divisions = 78 volts primary or 43,200 volts secondary.
10 divisions = 61 milliampères.
38 divisions = half cycle or $\frac{1}{120}$ second.
Maximum potential = 80,000 volts.
Maximum current = 52 milliampères.

3. The area enclosed in this loop is a measure of the energy of ionization. We may call the curve, if we like, an ionization hysteresis loop.

4. The energy which goes into ionization in the hydrogen tube is apparently a greater percentage of the total energy supplied

than in the M. & W. tube. Roughly speaking, it is estimated that about 40 per cent. of the energy supplied to the hydrogen tube goes into ionization, as against about 20 per cent. in the case of the M. & W. tube. This may account for the fact that more

FIG. 10.



Hydrogen tube.

Curve E. Plotted potential against time.
Curve I. Plotted current against time.
Curve E–I. Plotted current against potential.
Scales: 10 divisions = 89 volts primary or 40,800 volts secondary.
10 divisions = 61 milliampères.
39 divisions = half cycle or $\frac{1}{120}$ second.
Maximum potential = 79,100 volts.
Maximum current = 49 milliampères.

heat appears during operation in the latter case than in the former.

5. The arrows show the direction in which the loops are traced and indicate that there is an ionization potential distinct from the running potential. However, it is nothing of the order that is generally supposed. In the plot of Fig. 9 the descending and

ascending parts of the loop actually cross each other. This may be due to errors in measurement or possibly to the complexity of the gas in the M. & W. tube. In any event, the values of the potential needed to maintain any particular current are not widely divergent for the two sides of the loop.

In conclusion, it should again be pointed out that it is not best to carry interpretations too far at the present stage of the work. Certain errors are known to exist.

1. The plots represent an average over several half cycles. If the speed of the rotor changes, the apparent length of the cycle on the film will be altered in proportion and corrections must be made in measuring the ordinates.

2. If two films are used in two different holders involving two different frictions, another correction must be made to obtain corresponding ordinates before subtracting one from the other.

3. The arcs in the rectifying switch are not accurately set and involve gaps of varying lengths. These produce oscillations which make measurement difficult.

4. Finally, it should be stated that the curves shown here are for only three specific instances. However, other curves have been taken and plots made and they exhibit the same general characteristics.

A switch is now under development which will eliminate entirely all spark gaps in the secondary circuit. With this completed and in operation, most of the oscillations will be omitted and new plots can be made from a single exposure and for single cycles which will be dependable. In addition to investigating the characteristics of various tubes, it is hoped to also continue the investigation to determine the properties of spark gaps in general. Several other problems have been suggested to the writer during the course of the work and these, together with further results, will be reported at some future time.

This work is the outcome of research started last year in a slightly different field at the University of Pennsylvania. The work has been carried forward under the direction of Mr. H. Clyde Snook, to whom I am greatly indebted for many valuable suggestions and a large part of the apparatus used.

REFERENCES

[1] Dessauer, "Leitfaden des Röntgenverfahrens," 4th edition, 1912, p. 153.

[2] Fürstenau, "Die Technik der Röntgenapparate; Bibliothek der Gesamten Technik," Band 138, p. 15.

[3] Albers-Shönberg, "Die Röntgentechnik," 3d edition, 1910, p. 184.

[4] Kaye, *X-rays*, 1914, p. 99.

[5] Coolidge, *Physical Review*, December, 1911, p. 427.

[6] Cabot, *Archives of the Röntgen Ray*, September, 1911, p. 111.

[7] Snook, *American Quarterly of Röntgenology*, January, 1907.

[8] Duddell, *Journal of the Röntgen Society*, August, 1908.

[9] Wertheimer, *Journal of the Röntgen Society*, September, 1911.

[10] Bown, *Electrical World*, February 15, 1915.

[11] Snook, see above. Also, JOURNAL OF THE FRANKLIN INSTITUTE, October, 1907.

[12] Salomonson, *Journal of the Röntgen Society*, April, 1911.

Randal Morgan Laboratory of Physics,
University of Pennsylvania,
Philadelphia.

Alite the Chief Constituent of Portland Cement Clinker. E. JÄNECKE. (*Z. Anorg. Chem.*, lxxxix, 355.)—Alite, the mixture of composition, $8CaO, Al_2O_3, 2SiO_2$, was found to possess a maximum melting-point, 1385° C., in the ternary system, $CaO-Al_2O_3-SiO_2$, and it therefore probably represents a definite compound. It has a specific gravity 3.035, refractive index 1.63, and hardness 7 on Moh's scale. The substance known as alite, which crystallizes from cement clinker, exhibits all the properties of the above compound, and it is maintained, mainly on optical grounds, that the substances are identical.

Sugar Beet in Canada. F. T. SHUTT. (*Report of Dep. of Agric., Canada*, 1913, 242.)—Very satisfactory results have been obtained showing that sugar beets may be grown in widely distant parts of Canada. The highest sugar content, 17.86 per cent., was reached at Lethbridge, Alberta, and the lowest, 13.40 per cent., at Brandon, Manitoba, and at three of the experimental farms it averaged 17 per cent., the purity of the juice being over 90°.

Wireless Telegraphy. (*British Patent 27,480 of 1913.*)—A method of eliminating atmospherics, due to Marconi's Wireless Telegraph Company, Ltd., and H. J. Round, is described. The atmospherics aimed at are those which cannot ordinarily be tuned out. A receiving circuit slightly out of tune with the signal waves is employed, so that the induced free and forced oscillations are of suitable relative frequency to produce beats. These beats are rectified, and the detecting circuit is tuned to their frequency.

Recovery of Actinium and Ionium from the Olary Ores. S. RADCLIFFE. (*Chem. News,* cxi, 59.)—*Actinium.*—Almost the whole of this constituent appears to be precipitated with the mixed crude sulphates obtained in the course of extracting the radium. The mixture, containing about three per cent. of rare earths in addition to the constituents enumerated, is fused in an iron crucible with excess of sodium hydroxide containing some sodium carbonate, the melt extracted repeatedly with hot water, the insoluble residue digested with excess of sodium carbonate under a steam pressure of ninety pounds, the carbonate residue washed, treated with dilute hydrochloric acid, the solution evaporated to dryness, the residue treated with water, the silica filtered off, and the solution saturated with hydrochloric acid gas (to precipitate the radium and barium) and filtered. The filtrate, containing the actiniferous rare earths, is evaporated to dryness and the residue further treated to separate actinium. *Ionium* appears to be chemically inseparable from thorium, so that by extracting and purifying the latter by any of the well-known methods an active ionium product is obtained. The activity of this product depends on the ratio between the uranium and thorium present in the ore, this ratio being about 100:1 in the case of the Olary ore.

German Iron and Steel Production in 1914. ANON. (*Engineering,* Feb. 12, 1915.)—The Union of German Iron and Steel Industries states that the production of pig iron within the German Customs Union for December, 1914, amounted to 853,881 tons, against 1,611,250 tons for December, 1913, while there was an improvement as compared with November, 1914, for which the figure was 788,956 tons. The production of pig iron per day, since the war began, averaged: August, 18,925 tons; September, 19,336; October, 23,543; November, 26,299; December, 27,545 tons. The production for December comprised: Foundry pig, 148,881 tons; Bessemer pig, 8778; Thomas pig, 542,808; steel, etc., 128,347; puddle, 25,097 tons. The aggregate production of the different brands for the last two years was:

	1914	1913
Foundry pig	2,494,527	3,657,326
Bessemer pig	237,988	368,840
Thomas pig	9,289,989	12,193,336
Steel, etc.	1,996,786	2,599,887
Puddle	370,257	489,783
	14,389,547	19,309,172

The reduction in the production was most marked in Lorraine, Luxemburg, Rhineland, and Westphalia, while less pronounced in Silesia.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

THE EMERGENT STEM CORRECTION FOR THERMOMETERS IN CREOSOTE OIL DISTILLATION FLASKS.

Thermometers used in distillation flasks are subject to error if a portion of the thermometer stem, containing the mercury column, is emergent from the flask and is at a temperature different from that of the bulb.

This emergent stem correction error is discussed with particular reference to creosote oil distillation. Emergent stem corrections were determined, applicable to a particular type of thermometer when used in four types of distillation flasks.

The average correction found for the ordinary side neck distillation flask at 200° C. was 4.5°; at 250°, 6.0°; at 300°, 10.5°; and at 350°, 15.5°, with differences of as much as a degree between the same readings on different runs, making it evident that the average corrections could not be relied upon to better than a degree. For the same temperature, using the same thermometer in different flasks, the greatest difference in the stem corrections found was 2° C.

Reasons for variations in emergent stem corrections for different runs on the same flask are discussed. The greatest errors are caused by the use of unsuitable thermometers, and variations in the rate of rise. The most desirable thermometer for distillation flasks seems to be a continuous scale graduated stem type of mercurial thermometer having a length of about 40 cm.

The effect of radiation and condensed vapor on temperature measurement is discussed.

The magnitude of the disagreement in distillation results, when in one case allowance is made for stem correction and in another case it is not, is shown by example.

A method was suggested by which the total correction (including scale correction and emergent stem correction) to a thermometer used in distillation flasks can be determined at two points by reading the thermometer first in the vapor of boiling naphthalene

---

* Communicated by the Bureau.

(temperature 218° C.), and in the vapor of boiling anthracene (temperature 340° C.). Interpolations for the corrections between these two points can then be made. This method was investigated and found to be reliable to one or two degrees.

AN AIR-ANALYZER FOR DETERMINING THE FINENESS OF PORTLAND CEMENT.

By J. C. Pearson and W. H. Sligh.

[ABSTRACT.]

The increasing demand for more finely ground Portland cement has necessitated a further investigation of the value of fineness, particularly from an economic standpoint. An adequate investigation of this kind can be undertaken only when some further method of separating the "fines" from the No. 200 sieve is available, and therefore a number of attempts have been made in recent years to develop an elutriator for this purpose.

Two years' experience has shown that a satisfactory elutriator must meet the following fundamental requirements: (1) The apparatus should ensure, so far as possible, a constant velocity and uniform stream lines in the fluid as it passes through the separating chamber. (2) The fluid should not be appreciably retarded by the material under examination, or by constrictions or obstructions in that part of the apparatus beyond the separating chamber, unless the amount of such retardation can be determined by pressure gauges or compensated by special devices. (3) All particles of the material should be completely and continuously exposed to the action of the fluid, so that any which are capable of passing through the separating chamber may have every opportunity to do so. (4) The separating chamber should have no places of lodgement for material. (5) The apparatus should be capable of separating fair-sized samples, preferably 25 grammes or more. If these requirements are embodied in the construction of a given elutriator, its shape, dimensions, and working conditions are of secondary importance, and can readily be adapted to give the desired separations.

A review of earlier types of elutriators used or proposed for cement testing shows that some are faulty in design or unnecessarily complicated, while others are probably capable of making

good separations. Only one serious attempt appears to have been made to identify the separations in terms independent of the particular apparatus employed, and this not in a manner to enable comparisons to be made with results obtained by others.

After a series of preliminary experiments, an air-analyzer has been developed at the Bureau of Standards which seems to meet the fundamental requirements and appears to give reliable separations of cement and certain other materials. The distinguishing features of the apparatus are: the introduction of an unretarded air stream into a conical-shaped bulb in such manner that the sample under examination is completely and continuously exposed to the action of the air; a separating chamber of considerable height which permits no lodgement of either fine or coarse particles; a tapping device to minimize the adherence of fine dust to any part of the apparatus; and a collector which catches and holds all material passing through the separating chamber.

The main objection to elutriation methods appears to have been the lack of standardization of apparatus heretofore used. An endeavor has therefore been made to define the separations obtained by the air-analyzer in terms of the limiting sizes of particles in the different fractions. These limiting sizes, designated as the "sizes of separation," may be interpreted in different ways, depending upon the methods of measurement. Several methods of measurement have been studied, and a system has been provisionally adopted which appears to be the simplest and most direct, although not giving directly the "true diameters" of the particles under examination. The relations between the "apparent" and "true" sizes of particles have been expressed by means of reduction factors, which enable one to convert from one system to another.

A preliminary study has been made of the effects of abrasion, specific gravity, atmospheric conditions, and other factors on the separations, but much more work remains to be done before the limitations of the analyzer can be established with certainty. It seems probable that under normal operating conditions the nominal sizes of separation of the analyzer determined by calibrations with normal cements will be within about five per cent. of the actual sizes. This gives rise to a possible error of about 1.5 per cent. in estimating the quantity of any desired fraction from the mechanical analysis curve. As the error in determining the percentage of any given fraction by actual separation in the analyzer is probably not greater than 0.5 per cent., it may be assumed that routine analyses, without special calibrations, will enable one to determine the quantity of particles below a given size in any normal cement within two per cent. If greater accuracy is desired in special comparisons or in other important cases, calibrations can be made on the material under examination without excessive labor.

Further lines of investigation have been suggested, particularly in modifying the apparatus to yield still finer subdivisions. In making this change it is proposed to adapt the apparatus, if possible, to separations of organic and other powders which are not capable of withstanding the abrasive action produced by the air blast in the present type of bulb and nozzles.

The analyzer has been developed with the particular purpose in view of determining the granulometric composition of very finely ground and air-separated cements to be used in a further investigation of the value of fine grinding which is now under way. It is also adapted in its present form to comparisons of the products of different finishing mills, and to the separation and grading of abrasives and other hard-grained materials. In view of the considerable variety of finely-divided materials already tested with the analyzer, the apparatus promises to have a much broader field of usefulness than that for which it was originally designed.

THE CALCULATION OF THE MAXIMUM FORCE BETWEEN TWO PARALLEL, COAXIAL, CIRCULAR CURRENTS.

By Frederick W. Grover.

THE force of attraction or repulsion between two currents flowing in parallel, coaxial, circular paths of unequal radii increases as the distance between their planes is increased, until a maximum value of the force is reached, and then, as the distance is indefinitely increased, decreases toward zero as a limit.

It was shown by Maxwell that the distance for which the force is a maximum bears a ratio to either of the radii, which is a function of the *ratio of the radii alone,* and depends in no way on their absolute values. Further, the maximum value of the force, with unit current in each circuit, is also a function of the radii alone.

These facts have been utilized in the current balance, first used by Lord Rayleigh, in which is measured the force between two parallel, circular, coaxial coils, one fixed and the other attached to one end of the beam of a balance, the distance between the planes of the coils having been adjusted until the force exerted between the currents in the coils is a maximum. From the observed weights, which must be added to the other arm of the balance to restore equilibrium, the value of the current flowing through the two coils in series may be calculated, provided the ratio of the radii is known. The latter may be determined experimentally by an electrical method, without measuring the individual radii, and with an accuracy not attainable from direct measurements of the dimensions of the coils.

The calculation of the constant of the balance is based on the theory for two circular filaments to which the coils may be regarded as equivalent. The corrections necessary to be taken into account because of the finite cross-section of the coils have been derived by Rayleigh, Lyle, and others, and reference may be made to the paper on the " Determination of the International Ampère in Absolute Measure," by Rosa, Dorsey, and Miller, for a treatment of this question and for other details concerning the theory and methods of manipulation of the balance.

The force between two parallel, circular, coaxial currents of given radii, situated with any desired distance between their planes, may be calculated by the formula of Maxwell in elliptical integrals, or the formulas of Nagaoka which involve q series.

Previously, the value of the maximum value possible of the force between any two such circular currents, of given radii, has been obtained by calculating the force directly (by means of the formulas just mentioned) for a number of chosen distances of the coils in the neighborhood of the critical distance, which was supposed to have been approximately determined beforehand. The final value of the maximum force was determined by interpolation from this series of calculated values. This process is indirect and laborious.

In the present paper is derived a formula for calculating the value of the critical distance from the assumed ratio of the radii. By substituting the distance thus found in one of the above general formulas for the force, the maximum value of the force may at once be determined. In some cases the maximum force may be calculated directly from a formula given here in which this substitution has been made once for all.

The formula for the critical distance is, unfortunately, not simple enough to allow of the direct calculation of the critical distance from the given ratio of the radii. It is, however, not difficult to obtain the desired value with great accuracy by a method of successive approximation, provided a first approximation is at hand.

The latter part of the paper is devoted to the development of methods for facilitating this process. The formulas derived are fully illustrated by numerical examples, and tables are given of the critical distance and the value of the maximum force for such values of the ratio of the radii as are likely to occur in practice. It is further shown how the constants for coils, whose dimensions differ slightly from one of the exact ratios given in the tables, may be derived from the latter values with little trouble and labor.

To test the new formulas the complete calculations of the constants of the coils of the Bureau of Standards current balance have been carried through, and the results were found to be in agreement with the values obtained by the interpolation method within less than a part in a million.

THE EFFECTIVE RESISTANCE AND INDUCTANCE OF IRON AND BIMETALLIC WIRES.

By John M. Miller.

When a current of electricity flows through an iron wire the lines of magnetic force and the resulting magnetization of the iron are circular. From measurements of the self-inductance of the wire with direct current an exact permeability curve for circular magnetization can be obtained. As ordinarily measured, the permeability for axial magnetization is obtained. A comparison of the two kinds of magnetization shows that for some wires the permeability curves are similar, but for others the circular permeability may be considerably less than the axial. The differences are due probably to lack of homogeneity or isotropy of the iron caused by drawing and by heat treatment.

A method based upon Anderson's modification of the Maxwell bridge for measuring inductances is used to measure the effective resistance and inductance of six samples of iron telegraph and telephone wires and three samples of copper-clad steel, bimetallic wires. The measurements are made at frequencies up to 3000 cycles per second and with currents up to 10 ampères. The results are given by tables and curves. The so-called steel telephone wires are considerably poorer conductors at low frequencies and low current strengths than the grade called "Extra Best," but at higher frequencies and current strength the steel wires may be better conductors.

At the higher frequencies the resistance and inductance of the copper-clad wires become practically independent of the current flowing through the wire.

From considerations of bimetallic wires as two circuits in parallel, formulas are obtained which permit the computation of effective resistance and inductance of the wires. The core is treated as one circuit, the shell as another, and the self-inductance of each is computed as well as the mutual inductance of one on the other. Assuming no skin effect in the shell and introducing the effective resistance and inductance of the core for a given frequency, the resistance and inductance of the whole wire can be computed for that frequency from the expressions for the equivalent resistance and inductance of two circuits in parallel. The measured values of the copper-clad wire for low-current strengths are compared with the computed values, and the agreement is very satisfactory. The formulas are also used in computing wire tables for copper-clad steel wire. Values of effective resistance and inductance are tabulated for the even sizes from No. 0 to No. 12 A.W.G. for conductivities of 30, 40, and 50 per cent. of hard-drawn copper and for frequencies up to 1000 or 3000 cycles per second.

The Gyro-compass in the Navy. ANON. (*Sci. Amer.*, cxii, No. 7, 153.)—Gyro-compasses have now been installed on twenty battleships, one armored cruiser, and fifteen submarines of the United States Navy, and it has recently been decided to install master compasses in duplicate on all battleships of the *Delaware* class and later. Special attention is being paid to the instructions of officers and men in the care and use of these compasses by sending them for a month's instruction at the New York Navy Yard or at the works where the compasses are made. The Bureau of Navigation also maintains with the Atlantic fleet two chief gunners who have been specially trained as gyro-compass experts, their duty being to inspect and adjust the compasses and give instruction in their use.

India Rubber Production in 1914. S. FIGGIS AND CO. (*India Rubber J.*, xlix, 77.)—In 1914, 14,800 tons of plantation rubber were exported from Ceylon and India and 49,700 tons from Malaya, etc., as compared with 11,830 tons and 36,200 tons respectively in 1913; the 1914 figures do not include some direct Dutch shipments. The supply from Brazil, including Amazonas, Bolivia, Peru, etc., was 37,000 tons in 1914, against 39,000 tons in 1913. The total production of raw rubber in 1914 is estimated at 115,500 tons. Practically no guayule was made and less reclaimed rubber was used. Exports in 1914 from West Africa amounted to 8500 tons, from Loanda 450 tons, and from Congo, French Congo, and Sudan 3900 tons, the corresponding figures for 1913 being 10,000, 400, and 4400 tons respectively. England imported 2650 tons and France 1700 tons from West Africa in 1914.

Explosion of an Electric Transformer. ANON. (*Sci. Amer. Supple.*, lxxix, No. 2040, 89.)—The explosion of a large electric transformer in South Africa appears to have developed a new fact that was not known before. In taking down the transformer for repairs the workmen proceeded to drain the expansion tank located above the transformer of the oil it contained, and before doing so a man held a lighted match over a slight hole in the tank, when a severe explosion occurred that either killed or severely burned every man present, besides setting fire to everything inflammable in the transformer chamber. As the oil in the tank was not above 34° C., and its flash-point was 140° C., the gas that caused the explosion could not have been oil-vapor, and experiments were instituted, using extra high tension discharges under transformer oil. Samples of the resulting gases were collected, which on analysis proved to contain at least 62 per cent. hydrogen. It is evident, from this experience, that great care should be exercised not to allow a naked light near transformer oil tanks or oil switches until they have been thoroughly ventilated.

THE FRANKLIN INSTITUTE

(*Proceedings of the Stated Meeting held Wednesday, May 19, 1915.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 19, 1915.

PRESIDENT WALTON CLARK *in the Chair.*

Additions to membership, 3.

The Chairman recognized Dr. Harry F. Keller, who introduced Chevalier van Rappard, of Washington, D. C., and Mr. Thomas A. Edison, of Orange, N. J., to whom presentations of The Franklin Medal were made, that to Chevalier van Rappard being on behalf of the Royal Netherlands Government for Prof. Heike Kamerlingh Onnes, of Leiden, Holland.

The Chairman then recognized Dr. George A. Hoadley, who introduced Mr. Samuel Insull, of Chicago, Ill., founder of The Franklin Medal Fund, to whom was presented a sculptor's model in bronze of The Franklin Medal.

After the presentations, Mr. Insull delivered an address, entitled "Electricity and Modern Industrial Growth," which was illustrated by lantern slides.

Adjourned.
R. B. OWENS,
Secretary.

(A full account of the meeting will appear in the next issue.)

CORRESPONDENCE.

LEIDEN, 27 April, 1915.

DR. R. B. OWENS, *Secretary of*
The Franklin Institute of the State of Pennsylvania, Philadelphia.

SIR:

I beg to express my sincere gratitude for the honour The Franklin Institute has bestowed upon me by awarding me The Franklin Medal.

The appreciation of my labors in low-temperature research by The Franklin Institute is a great satisfaction for me.

I regret that it is not possible for me to come to the meeting of 19 May next, and I beg to thank you for inviting Chevalier W. F. L. C. van Rappard, my Government's Minister at Washington, to have the kindness to receive the medal and certificate on behalf of my Government for me.

I am respectfully,

[Signed] H. KAMERLINGH ONNES.

FROM THE LABORATORY
OF
THOMAS A. EDISON,

ORANGE, N. J., April 14, 1915.

MR. R. B. OWENS, *The Franklin Institute*
of the State of Pennsylvania, Philadelphia, Pa.

DEAR MR. OWENS:

I received both your official and personal letters in regard to the action of Institute in awarding me The Franklin Medal, and was greatly surprised, as this was the first intimation I had of any such thing.

I shall not attempt to say how deeply I am gratified on this mark of distinction, because I am unable to do so adequately. Let me say, however, that I am deeply appreciative of the honor thus conferred upon me, and I thank you for your personal congratulations and kind expression of sentiment in regard to myself.

. . . .

With kind regards, I remain,

Sincerely yours,

[Signed] THOMAS A. EDISON.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, May 5, 1915.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 5, 1915.

MR. G. H. CLAMER *in the Chair.*

The following reports were presented for final action:

No. 2613.—Anderson Gear Rolling Machines. John Scott Legacy Medal and Premium recommendation to Harold N. Anderson, of Cleveland, Ohio, adopted.

No. 2633.—Owens Bottle Making Machine. Elliott Cresson Medal to Michael J. Owens, of Toledo, Ohio, adopted.

On the recommendation of the Subcommittee on Literature, the following awards were made for papers in the JOURNAL, 1914:

No. 2645.—The Howard N. Potts Medal to Dr. William J. Humphreys, of Washington, D. C., for his paper entitled "The Thunderstorm and Its Phenomena," described by the subcommittee as an original, comprehensive, and authoritative presentation of the phenomena of the thunderstorm.

No. 2646.—The Edward Longstreth Medal of Merit to Dr. Herbert E. Ives, of Philadelphia, Pa., for his paper entitled "Artificial Daylight," described by the subcommittee as an account of important original investigations in the field of illumination.

No. 2647.—The Edward Longstreth Medal of Merit to Dr. M. von Recklinghausen, of New York, N. Y., for his paper entitled "The Ultra-violet Rays and their Application for the Sterilization of Water," described by the subcommittee as a lucid description of a novel and practical application of ultra-violet rays.

No. 2648.—The Edward Longstreth Medal of Merit to Mr. C. C. Tutwiler, of Philadelphia, Pa., for his paper entitled "The Recovery of Gas Works By-products," described by the subcommittee as a comprehensive account of the most recent developments in this field.

No. 2649.—The Edward Longstreth Medal of Merit to Mr. C. D. Young, of Altoona, Pa., for his paper entitled "Locomotive Superheaters and their Performance," described by the subcommittee as a thoroughgoing review of the development of the locomotive superheater, together with an account of a highly valuable research.

R. B. OWENS,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, May 12, 1915.*)

RESIDENT.

MR. WILLIAM H. HARDING, 1722 Land Title Building, Philadelphia, Pa.
MR. WILLIAM STANTON TWINING, 119 Harvey Street, Germantown, Philadelphia, Pa.

ASSOCIATE.

MR. HENRY RAWLE PEMBERTON, 1008 Clinton Street, Philadelphia, Pa.

CHANGES OF ADDRESS.

MR. FRANK M. ASHMEAD, 445 Ashland Avenue, Buffalo, N. Y.
MR. WALTER F. BALLINGER, northwest corner Seventeenth and Arch Streets, Philadelphia, Pa.
MR. EDWARD L. COSTER, Room 1440, 25 Broad Street, New York, N. Y.
MR. E. L. GIBBS, 602 King Street, Jacksonville, Fla.
MR. D. W. LUM, 1024 Munsey Building, Washington, D. C.
MR. EMILE G. PERROTT, northwest corner Seventeenth and Arch Streets, Philadelphia, Pa.
MR. ROBERT S. REDFIELD, Barnstable, Mass.
MR. ALBERT R. SHIPLEY, Thomaston, Conn.
MR. ORIN C. STOUT, 509 Hartman Building, Columbus, Ohio.
MR. ELLIS D. WILLIAMS, Box 274, Jenkintown, Pa.
MR. HERBERT W. YORK, 120 Broadway, New York, N. Y.

NECROLOGY.

John Birkinbine, ex-president of The Franklin Institute, a consulting engineer of international reputation, a pioneer in mining, metallurgical and blast-furnace construction, ended a long and eminently useful life at his home in Cynwyd, a suburb of Philadelphia, on Friday, May 14, 1915. He was born in Reading, Pa., November 16, 1844, the eldest son of H. P. M. Birkinbine, whose widely-recognized accomplishments in the field of hydraulic engineering established a name which the son, through a lifetime of successful effort, carried forward into the foremost rank of the engineering profession, and which his sons, in turn, are maintaining with honor in their generation.

John Birkinbine was educated in the public schools of his native city and in the Friends High School in Philadelphia, the Hill School at Pottstown, and the Polytechnic College of Philadelphia. His studies were interrupted in 1863-4 by his twice enlisting for scout duty in the Union Army, in which capacity he participated in the Gettysburg battles and campaign. In later years he was offered honorary degrees by two colleges, but modestly declined these on the ground that, having been unable to graduate from his own Alma Mater, he was not warranted in accepting them.

Following his army experience, young Birkinbine devoted two years to practical work in a machine shop and then took part in the firm of Weimer & Birkinbine, which operated the Weimer Machine Works at Lebanon, Pa. Thereafter he became associated with his father and had charge of much of the field work and construction which his father had in hand. Collaborating with him in the design and execution of various public water works, the utilization of water powers, and other similar undertakings, and clarifying his experiences by constant study, he soon attained a position of prominence as an expert consultant in important undertakings of this kind. Gradually his work became extended in the direction of mining, metallurgical and blast-furnace construction. As manager for the South Mountain Mining and Iron Company he carried through a series of experiments with various fuels for melting iron ore in continuous furnace operation. The carefully-recorded results which he obtained were widely published and are included in text-books as the most authentic data on the subject.

Mr. Birkinbine was called to nearly every State in the Union, to Canada and to Mexico, to make examinations and reports on the construction or improvement of iron ore mines, blast furnaces, iron works, water supplies, hydraulic development, irrigation projects, etc., his services in these directions having been requisitioned on a number of occasions by European corporations. Among his many expeditions of this nature, several were to Mexico, beginning with a journey to the Cerro de Mercado at Durango, before any railroad had been built in that region, there to make a critical examination and report on the "Iron Mountain." Later visits, covering other localities in Mexico and dealing with other engineering problems, familiarized him with the major part of the iron industry in that country. The enlargement, modernization, and improvement of much of the iron and steel industry of Mexico upon which he reported, after investigations made for various in-

JOHN BIRKINBINE
1844—1915

terests in Europe and America, await only the end of the present political disturbances in our neighboring republic.

Mr. Birkinbine was probably the first to suggest an iron industry at the head of the Great Lakes, using coke made from Pennsylvania coal; his report on the subject became an important factor in determining the establishment of the iron industry at the head of Lake Superior, and the blast furnace at West Duluth, Minn., was built on his plans and under his supervision. For some years he was consulting engineer for the Philadelphia and Reading Coal and Iron Company, and held a similar position with Mr. Thomas A. Edison during the early course of the experiments carried on by the latter on magnetic concentration of iron ore, with Witherbee, Sherman & Company in beneficiation tests, and with the Colorado Fuel and Iron Company in the enlargement and improvement of its works and the construction of an augmented water supply system. He acted on various occasions as expert for important financial interests, for a number of the greatest industrial corporations and for several of the large railroad companies in this country. His reports and recommendations are characterized by their clearly-stated conclusions, and his reputation for conservatism and fairness led to his being called upon for appraisements, adjustments, and arbitrations, in some of which he was accepted by mutual consent as the representative of both parties. To maintain his position of independence in this regard he declined all offers of contingent fees and refrained from patenting any of the numerous improvements which he originated.

Throughout his career Mr. Birkinbine made a specialty of hydraulic engineering, acting as engineer on water supplies for various municipalities. He not only witnessed but actively participated in the extensive application of water power for electrical energy which has marked these recent years. In 1888 he prepared a comprehensive report on the utilization of the great water power of the St. Louis River in Minnesota, taking a view of a 15-mile transmission, though no water-wheel manufacturer at that time would guarantee turbines for heads above thirty-five feet. Since then he has been associated with or reported on many hydraulic developments in various States of the Union and in Mexico, dealing with high heads or large volumes of water which until lately were regarded as impracticable.

The general interests of the engineering profession and the advancement of the sciences and arts in general evoked Mr. Birkinbine's active coöperation. Besides serving through the ten years from 1897 to 1907 as president of The Franklin Institute and through the rest of his years as member of its Board of Managers, he early participated in the activities of various other scientific societies. He took a leading part in organizing the Pennsylvania Forestry Association in 1886, and was its president for twenty-three years, during which period the association procured the establishment of a State Forestry Commission, latterly made a State department, and the enactment of various laws in furtherance of the forestry movement. The Bulletin of the Association, *Forest Leaves,* was edited by him from its inception to the date of his death. He was chairman of the Water Supply Commission of Pennsylvania from the time of its organization in 1905, devoting to its duties a large portion of his valuable time for a merely nominal recompense. For two-score years he continued prominent in the American Institute of Mining Engineers, having been manager, vice-president, and president, being reëlected to this latter office to the limit set by the constitution, and he contributed largely to its proceedings and to other technical periodicals.

He was active in the formation and served as secretary of the United States Association of Charcoal Iron Workers, and for nine years edited its journal. For many years he was special agent for the United States Geological Survey, preparing the reports on iron ores for the eleventh and twelfth censuses, that on manganese ores for the twelfth census, and latterly additional data and studies for the Survey. He was appointed by the Secretary of the Interior expert metallurgical engineer for the Bureau of Mines, and received special marks of approval from the Survey and from several foreign scientific societies. He was a member of a number of international congresses, chief engineer, vice-president, and chairman of the Committee of Awards of the National Export Exposition, served on juries of award at the Centennial, Columbian, Pan-American, and Cotton States Expositions, and was named for similar duties at others. He was a member of the American Society of Mechanical Engineers, the Engineers' Club of New York, the American Society for Testing Materials, The Engineers' Club of Philadelphia (president in 1893), The Manufacturers' Club of Philadelphia, The Pennsylvania Foundrymen's Association, and an honorary member of the Canadian Mining Institute. He was also connected with the George G. Meade Post, No. 1, G. A. R., of Philadelphia. He became a member of The Franklin Institute in 1865.

Mr. Birkinbine constantly maintained a friendly interest in his fellow-members of the profession, and held to the thought that engineers were coöperators and not competitors. He continued his personal interest in all his associates and was ever ready to help young men by advice.

As a citizen he was always active in promoting the public good. He served on the Civil Service and other commissions, besides rendering professional services for the city of Philadelphia. His neighborly activities were maintained up to the end of his life. His last days were happily spent in the circle of his family, for as a devoted husband and father he fulfilled with a deep religious consciousness what he considered his greatest pleasure and the noblest of all his duties, those to his family and his home.

LOUIS EDWARD LEVY.

Charles Martin Hall was born at Thompson, Ohio, on December 6, 1863. He was graduated from Oberlin College in 1885 with the degree of Bachelor of Arts, and received his degree of Master of Arts in 1893 and of Doctor of Laws in 1910. He invented, in 1886, the electrolytic process for the manufacture of aluminum now universally used. Two years later he commenced the commercial manufacture of aluminum with the Pittsburgh Reduction Company. His invention of the aluminum process was in litigation for some years, but he was ultimately conceded priority. His process was a poten factor in reducing the price of this metal, which was formerly as costly a silver.

He was a member of the American Philosophical Society and of the American Institute of Mining Engineers. He was awarded the Perkin Medal for his work in chemistry in 1911.

He was elected a member of the Institute in 1909.

He died on December 27, 1914.

Mr. Samuel Bancroft, Jr., Rockford, Wilmington, Del.
Mr. James R. Magee, 1720 Walnut Street, Philadelphia, Pa.

LIBRARY NOTES.

PURCHASES.

Blücher, H.—Moderne technik: die wichtigsten Gebiete der Maschinentechnik. 2 volumes. 1912.

Böckler, G. A.—Theatrum machinarum novum. 1686.

Clennell, J. E.—Cyanide Handbook. 1915.

Davies, John P.—Engineering Office Systems and Methods. 1915.

Dyer, F. L., and Martin, T. C.—Edison—His Life and Inventions. 2 volumes.

Haven, G. B., and Swett, G. W.—Design of Steam Boilers and Pressure Vessels. 1915.

Holde, D.—Examination of Hydrocarbon Oils and Saponifiable Fats and Waxes. 1915.

Horsburgh, E. M., ed.—Modern Instruments and Methods of Calculation. No date.

Houston, A. C.—Studies in Water Supply. 1913.

Hovgaard, W.—Structural Design of Warships. 1915.

Le Blanc, Max.—Production of Chromium and its Compounds. 1904.

Leffmann, Henry.—Examination of Water for Technical and Sanitary Purposes. 1915.

Melan, J.—Plain and Reinforced Concrete Arches. 1915.

Moritz, E. A.—Working Data for Irrigation Engineers. 1915.

Nissenson, H.—Arrangement of Electrolytic Laboratories. 1905.

Richardson, O. W.—Electron Theory of Matter. 1914.

Richey, A. S.—Electric Railway Handbook. 1915.

Taylor, W. W.—Chemistry of Colloids, and Some Technical Applications. 1915.

GIFTS.

brasive Material Company, Catalogue of Grinding Wheels. Philadelphia, no date. (From the Company.)

merican Gas Institute, Proceedings, vol. ix, parts i and ii, 1914. New York, 1915.

merican Institute of Electrical Engineers, Catalogue of the Wheeler Gift of Books, Pamphlets and Periodicals. New York, 1909. (From the Institute; second copy from Mr. Washington Devereux.)

merican Institute of Mining Engineers, Transactions, vol. xlviii, 1914. New York, 1915. (From the Institute.)

American Iron and Steel Institute, Annual Statistical Report, 1913. Philadelphia, 1914. (From the Institute.)

American Society of Mechanical Engineers, Rules for the Construction of Stationary Boilers and for Allowable Working Pressures. New York, 1914. (From the Society.)

Atlantic Deeper Waterways Association, Proceedings of Seventh Annual Convention, 1914. New York, 1915. (From the Association.)

Bantam Anti-Friction Company, Official Blue Book of Ball and Roller Bearings. Bantam, Ohio, 1915. (From the Company.)

Bridgeport Brass Company, Hand Book for Architects, Engineers and Superintendents. Bridgeport, Conn., no date. (From the Company.)

Canada Department of Mines, Memoirs 65 and 66, Clay and Shale Deposits of the Western Provinces; Memoir 61, Moose Mountain District, Southern Alberta; Preliminary Report on the Bituminous Sands of Northern Alberta; Report, 1913; Bulletin No. 9, Investigation of the Peat Bogs, 1911–1912; Annual Report on the Mineral Production of Canada, 1913. Ottawa, 1914. (From the Department.)

Canada Geological Survey, Memoir No. 38, North American Cordillera, parts ii and iii. Ottawa, 1912. (From the Survey.)

Canadian Archives, A Guide to the Documents in the Manuscript Room at the Public Archives of Canada, vol. i. Ottawa, 1914. (From the Archivist.)

Celfor Tool Company, Catalogue No. 15 of High-speed Twist Drills and Internal Gear Drive Axles. Buchanan, Mich., no date. (From the Company.)

College of Physicians, Transactions, Third Series, vol. xxxvi. Philadelphia, 1914. (From the College.)

Commission of Fine Arts, Message from the President of the United States Transmitting the Report of the Commission, 1914. Washington, 1915. (From the Commission.)

Connecticut State Board of Health, Thirty-third Report, 1914. Hartford, 1915. (From the Board.)

Dake Engine Company, Catalogue of Steam and Air Motors and Pneumatic Hoists. Grand Haven, Mich., no date. (From the Company.)

Dobbie Foundry and Machine Company, Catalogue No. 18 of Derricks. Niagara Falls, N. Y., 1915. (From the Company.)

Drew Electric and Manufacturing Company, Catalogue No. 3 of Electric Railway, Light and Power Materials. Indianapolis, 1914. (From the Company.)

Florida State Railroad Commission, Eighteenth Annual Report. Tallahassee, 1915. (From the Commission.)

Franklin Printing Company, "Benjamin Franklin—Founder," The Remarkable Record of a Philadelphia Institution from 1728 to 1915. Philadelphia, 1915. (From the President of the Company.)

Gorton Machine Company, Catalogues Nos. 2-E and 2-B. Racine, Wis., 1915. (From the Company.)

Hartford Steam Boiler Inspection and Insurance Company, "The Locomotive," vol. xxvii. Hartford, Conn., 1908–1909. (From Mr. S. B. Adams.)

Hunter & Dickson Company, Catalogue No. 10 of Williams Steam Specialties. Cincinnati, 1915. (From the Company.)

Hydraulic Press Manufacturing Company, Catalogue No. 40 of Hydraulic Presses. Mount Gilead, Ohio, no date. (From the Company.)

Institution of Civil Engineers, Minutes of Proceedings, vol. cxcviii, part iv, 1913–1914. London, 1915. (From the Institution.)

K. Vitterhets Historie Och Antikvitets Akademien, Fornvannen. Stockholm, 1914. (From the Akademien.)

Leland Stanford Junior University, Register; Annual Report of the President, 1914. Stanford University, Cal., 1915. (From the University.)

Library of Congress, Washington Papers, Correspondence with the Officers, vols. i–iv, 1775–1784, and Index. Washington, 1915. (From the Library.)

Library of the Patent Office, Patent Office Library Series: No. 1, 3d edition. London, 1915. (From the Patent Office Library.)

Locomotive Stoker Company, Publications Nos. 11 and 12 of Instructions for Operating, Oiling and Maintaining Types B and C of the Street Locomotive Stoker. Schenectady, 1914. (From the Company.)

Maine Department of Labor and Industry, Report 1913–14. Waterville, 1915. (From the Department.)

Massachusetts Board of Education, Seventy-eighth Annual Report, 1913–1914. Boston, 1915. (From the Board.)

Minnesota Railroad and Warehouse Commission, Thirtieth Annual Report, 1914. Minneapolis, 1915. (From the Commission.)

Nevada Railroad Commission, Annual Report, 1914. Carson City, 1915. (From the Commission.)

New York State Library, Ninety-fifth Annual Report, 1912. Albany, 1914. (From the Library.)

Northern Central Railway Company, Sixtieth Annual Report, 1914. Philadelphia, 1915. (From the Company.)

Ohio Industrial Commission, Report No. 3, Statistics of Mines and Quarries in Ohio, 1913. Columbus, 1915. (From the Commission.)

Ontario Department of Agriculture, Report, vols. i and ii, 1913; Report of Horticultural Societies, 1914. Toronto, 1915. (From the Department.)

Pennsylvania Commissioner of Banking, Report, Part i, 1914. Harrisburg, 1915. (From the State Librarian.)

Pennsylvania Railroad Company, Sixty-eighth Annual Report, 1914. Philadelphia, 1915. (From the Secretary.)

Pennsylvania Topographic and Geologic Survey, Report, 1913–14. Harrisburg, 1914. (From the State Librarian.)

Pittsburgh, Cincinnati, Chicago and St. Louis Railway Company, Twenty-fifth Annual Report. Pittsburgh, Pa., 1915. (From the Company.)

Rose Polytechnic Institute, April Bulletin. Terre Haute, Ind., 1915. (From the Institute.)

Steam Appliance Company, Catalogue No. 18 of Steam Specialties. Milwaukee, Wis., 1913. (From the Company.)

Syracuse University, University Number of Bulletin. Syracuse, N. Y., 1915. (From the University.)

Taunton Water Board, Report, 1914. Taunton, Mass., 1915. (From the Board.)

Thayer, M. Russell, "The Life, Character, and Writings of Francis Lieber." Philadelphia, 1873. (From Dr. Carl Hering.)

United States Army, Register. Washington, 1915. (From the Secretary of War.)

United States Coast and Geodetic Survey, Special Publication No. 24, Triangulation in Alabama and Mississippi. Washington, 1915. (From the Survey.)

United States Electrical Tool Company, Catalogue No. 12 of Portable Electrical Tools. Cincinnati, 1915. (From the Company.)

United States Navy, Register. Washington, 1915. (From the Secretary of the Navy.)

University of Colorado, Catalogue. Boulder, 1915. (From the University.)

University of North Dakota, General Catalogue. University, 1915. (From the University.)

University of Pennsylvania, Catalogue of University Lectures Delivered by Members of the Faculty in the Free Public Lecture Course, 1913–1914. Philadelphia, 1915. (From the University.)

University of Vermont, Catalogue. Burlington, 1915. (From the University.)

Ursinus College, Bulletin. Collegeville, 1915. (From the College.)

Veritys Limited, Catalogue of Electric Supplies, vol. ii. London, no date. (From the Company.)

Washington University, Catalogue. St. Louis, Mo., 1914. (From the University.)

Webster, Warren, & Company, Catalogue of Modulation System of Steam Heating. Camden, 1915. (From the Company.)

Weinman Pump Manufacturing Company, Catalogue of Steam and Power Pumping Machinery. Columbus, Ohio, no date. (From the Company.)

Whitman & Barnes Manufacturing Company, Catalogue No. 86 of Machinists' Supplies. Akron, Ohio, 1915. (From the Company.)

Wisconsin Geological and Natural History Survey, Mine Valuation and Assessment; Polyporaceæ of Wisconsin. Madison, 1914. (From the Survey.)

York Manufacturing Company, Ice Making and Refrigerating Data and Catalogue. York, Pa., no date. (From the Central Construction and Supply Company.)

PUBLICATIONS RECEIVED.

Explosives: Their Manufacture, Properties, Tests, and History, by Arthur Marshall, A.C.G.I., F.I.C., F.C.S., Chemical Inspector, Indian Ordnance Department. 624 pages, illustrations, 4to. Philadelphia, P. Blakiston's Son & Co., 1915. Price, $7 net.

Spencer Fullerton Baird: A Biography, including selections from his correspondence with Audubon, Agassiz, Dana, and others, by William Healey Dall, A.M., D.Sc. 462 pages, illustrations, plates, portraits, 8vo. Philadelphia and London, J. B. Lippincott Company, 1915. Price, $3.50 net.

Electrical Instruments in Theory and Practice, by W. H. F. Murdoch and U. A. Oschwald. 366 pages, illustrations, 12mo. London, Whittaker & Co., 1915. Price, 10s.6d. net.

Canada, Department of Mines: Summary Report of the Mines Branch for the Calendar Year Ending December 31, 1913. 214 pages, illustrations, tables, plates, maps, 8vo. Annual Report on the Mineral Production of Canada During the Calendar Year 1913, by John A. McLeish, B.A., Chief of the Division of Mineral Resources and Statistics. 363 pages, 8vo. Preliminary Report on the Bituminous Sands of Northern Alberta, by S. C. Ells. 92 pages, illustrations, plates, maps, 8vo. Investigation of the Peat Bogs and Peat Industry, by A. v. Anrep. 47 pages, illustrations, plates, tables, maps, 8vo. Preliminary Report on the Mineral Production of Canada During the Calendar Year 1914, prepared by John McLeish, B.A., Chief of the Division of Mineral Resources and Statistics. 24 pages, 8vo. Ottawa, Government Printing Bureau, 1914 and 1915.

U. S. Bureau of Mines: Bulletin 80, A Primer on Explosives for Metal Miners and Quarrymen, by Charles E. Munroe and Clarence Hall. 125 pages, illustrations, plates, 8vo. Bulletin 81, The Smelting of Copper Ores in the Electric Furnace, by Dorsey A. Lyon and Robert M. Keeney. 80 pages, illustrations, 8vo. Bulletin 87, Houses for Mining Towns, by Joseph H. White. 64 pages, illustrations, plates, 8vo. Bulletin 88, The Condensation of Gasoline from Natural Gas, by George A. Burrell, Frank M. Seibert and G. G. Oberfell. 106 pages, illustrations, plates, 8vo. Technical Paper 81, The Vapor Pressure of Arsenic Trioxide, by H. V. Welch and L. H. Duschak. 20 pages, illustrations, plate, 8vo. Technical Paper 89, Coal-tar Products and the Possibility of Increasing their Manufacture in the United States, by Horace C. Porter, with a chapter on Coal-tar Products Used in Explosives, by C. G. Storm. 21 pages, 8vo. Technical Paper 90, Metallurgical Treatment of the Low-grade and Complex Ores of Utah, a preliminary report by D. A. Lyon, R. H. Bradford, S. S. Arentz, O. C. Ralston, and C. L. Larson. 39 pages, 8vo.

Harrison Safety Boiler Works, Cochrane Engineering Leaflet No. 18, Testing V-notch Meters. 48 pages, illustrations, 8vo. Philadelphia, Harrison Safety Boiler Works, 1915.

North Pole Aftermath, speech by Hon. S. D. Fess, of Ohio, in the House of Representatives, Congress of the United States, Thursday, March 4, 1915. 27 pages, 8vo. No place, no date.

U. S. Department of Agriculture, Bulletin 210, Seed Production of Western White Pine, by Raphael Zon, Chief of Forest Investigations. 15 pages, 8vo. Washington, Government Printing Office, 1915.

Great Men and How They are Produced, by Caspar L. Redfield. 32 pages, 8vo. Chicago, Author, 1915. Price, 15 cents.

CURRENT TOPICS.

Production of Explosives in the United States in 1913. A. H. Fay. (*Tech. Paper No. 85, U. S. Bureau of Mines,* 1914.)—The total production of explosives in the United States in 1913 was 463,514,881 pounds, a decrease of 25,878,250 pounds from the production in 1912. The production of black powder amounted to 194,146,747 pounds, permissible explosives 27,685,770 pounds, and other high explosives 241,682,364 pounds. In the coal mines of the United States 209,352,938 pounds of explosives were used in 1913 to produce 570,048,125 tons of coal; this is an increased production from 2.36 to 2.72 tons of coal per one pound of explosive over 1912. The use of permissible explosives in coal mines continues to increase.

Melting Metal Wires into Quartz-glass Vessels. R. Shaller. (*Zeitschr. Instrumentenk. Beib.,* xii, 130.)—It is often desired to attach ordinary glass, capable of being worked in the usual furnaces, to quartz glass which requires special treatment, particularly when only a small portion of a large and complicated vessel needs to be made of the latter variety. Owing to the exceptionally small coefficient of expansion and the high melting-point of quartz glass, the immediate attachment to it of ordinary glass and the direct melting-in of platinum wire are impossible. The junction can be accomplished only by a series of glasses with a gradual transition of qualities. These require special working: the nearer the qualities of quartz glass being approached, the hotter has to be the temperature of the blast flame, and either the oxyhydrogen or the oxy-coal gas flame must be employed. Platinum on account of its chemical properties, is convenient for leading-in wires, but, as its coefficient of expansion is relatively high, a large number of transition glasses are needed. In this respect tungsten and molybdenum are preferable; their cubical expansion coefficients are 130×10^{-7} and 150×10^{-7}, and they can therefore easily be melted into glass whose coefficient is between 100 to 170×10^{-7}. Iron-nickel alloys, which have a very low coefficient of expansion, do not give safe, gas-tight joints, because the coefficient admittedly increases rapidly with rising temperature.

Units of Weight and Measure. (*Bureau of Standards,* Circular No. xlvii, Washington, 1914.)—This circular is to supersede the Bureau of Standards Miscellaneous Publication on "Tables of Equivalents of the U. S. Customary and Metric Weights and Measures," and contains an extensive series of tables. The units are defined and their interrelation shown in tables, and tables are also given of equivalents from 1 to 999 units. Some special tables are appended, such as: Millimetres and decimal and binary fractions of an inch; hundredths of an inch to millimetres, and *vice versa;* comparisons of various pounds and tons in use in the United States; comparison of prices (French, German, English, and United States).

Radium as a Lightning Conductor. B. SZILARD. (*Soc. Int. Elcct.*, Bull. iv, 669.)—The ordinary point-lightning conductor is discussed from an efficiency standpoint and its limitations are explained. The author then proposes an ionization method for preventing electric storms by means of radium, disclaiming originality, however, by a reference to Arago in which flames were used with the same object. We now know that the flames would ionize the atmosphere; the radium, however, would exert other influences in addition to ionization towards the same end. A considerable section of this paper is then devoted to an exposition of the influence of radium emanations upon the electrical conductivity of air. Following this comes a theoretical discussion of the effects which would follow if an ordinary lightning conductor were furnished with a radium-covered screen placed beneath the point. The net results would seem to be a progressive conductivity of the air towards the point, which would promote the electrical flow in this direction. A detailed description next follows of a radium-furnished instrument for the practical study of the subject The apparatus was provided with a suitable installation for the quantitative examination of the phenomena observed. The whole scheme was specially designed for easy portability. The results obtained are well explained and illustrated by a series of comparison curves. The author believes that work on these lines merits further investigation.

Lag in Marine Barometers on Land and Sea. C. CHREE. (*Meteorologist Office,* Geophys. Mem. viii, 173.)—The marine barometer is a so-called "Kew Pattern" barometer, in which a portion of the tube is specially constricted in order to introduce great resistance to rapid motion of the mercury and so enable accurate pressure readings to be made on board ship even when the sea is very rough when an ordinary mercury barometer cannot be read with accuracy on account of "pumping" of the column of mercury. The "Kew Pattern" barometer is one in which the capacity correction is allowed for by suitable gradation of the scale in "apparent" inches, not true inches.

In 1880 Stokes discussed the theory of the sluggishness of the marine barometer and found that when pressure is changing uniformly the reading of the barometer should be the same as the true reading L minutes previously where L is the "lagging time" of the instrument, and is equal to 0.91 × time taken by the mercury to fall the inch from 1½ to ½ inch above the true level of the barometer at the time. This result does not depend upon the rate at which pressure is changing.

From experiments made at Kew Observatory with two marine barometers it is shown that, in fact, the effect of lag is much greater than according to Stokes's formula, and that it depends partly upon the rate at which the pressure is changing. Thus the ratio of the observed to the calculated lagging-time varies from 10 or 12 when the rate of pressure-change per hour is 0.0058 inch to 5 or 6 when the rate is 0.0242 inch per hour. On the other hand, readings made at sea on board the steamship *Hesperian* with the same two barometers appear to indicate that on board ship the effect of lag is exceedingly small, even smaller than it should be according to Stokes's formula.

Characteristic Equations of Tungsten Filament Lamps and Their Application in Heterochromatic Photometry. G. W. MEDDLEKAUFF and J. F. SKOGLAND. (*Am. Illum. Eng. Soc. Trans.*, ix, 734.)—This paper gives an account of the difficulties experienced at the Bureau of Standards in calibrating lamps differing in color from the 4-watt-per-candle carbon primary standards which maintain the international candle. Comparison of lamps of the same color involves no special difficulties, but when a color difference exists there is a want of agreement in the results obtained by experienced observers, due principally to two causes: (*a*) Difference in color vision; (*b*) difference in judgment of intensity. Hence to establish standards it is not only necessary to have observers of normal color vision, but also to obtain a very large number of readings by experienced observers. In the photometry of different colored lights the only methods which are sufficiently sensitive are: (1) Flicker, (2) equality of brightness. At the Bureau of Standards more consistent results have been obtained by using (2). The method proposed by the authors for surmounting the various difficulties consists in using tungsten secondary standards, which can be adjusted to a color match with all incandescent lamps and approximately with flame lamps. These are measured at a match in color directly in terms of the primary standards, and their candle-powers are determined from the corresponding measured voltages. This is done by the use of characteristic equations which the authors have derived from the results of measurements of tungsten lamps of various sizes and makes. In determining these equations the difficulties due to color difference are dealt with once for all. Tables of values computed by means of these equations are given for use in practical photometry. In the discussion, F. E. Cady emphasized the fact that the method does not eliminate the color difference in photometry, but merely localizes it in one place. P. G. Nutting suggests other methods of overcoming the color difficulty. The authors, in reply, pointed out that the color-difference difficulties are encountered once for all, and it is immaterial as to whether it is done by means of an equality-of-brightness or a flicker photometer. The only effect resulting from a possible difference in value obtained by the use of the flicker photometer would be a slight change in the constants of the equations. In the National Physical Laboratory the step from the carbon standards is made by the cascade method, while at the Bureau of Standards it is made by the use of two calibrated blue glass screens of practically the same transmission coefficient.

The Transverse Testing of Cast Iron. G. HAILSTONE. (*Iron and Steel Inst. J.*, xc, 82.)—The author describes a special machine which has been designed for making transverse tests on cast-iron bars of different dimensions. A series of tests has been made on a range of mixtures from weak to strong cast irons using test-bars 2 × 1 inch in section tested on 36-inch centres and 1-inch square bars tested on 12-inch centres. The results show that the ratio of the strengths is 1.153 for machined bars and 1.146 for bars tested with the skin on, instead of 1.333 as originally allowed for in the standard English specifications. The best standard test-bar, giving the most consistent and comparable results, is the one cast to $2\frac{1}{8} \times 1\frac{1}{8}$ inches in section and 42 inches in length and machined to 2 × 1 inch and tested on 36-inch centres. The rate of loading should not exceed one hundredweight in 15 seconds, this being a very convenient rate.

Spectra of Magnesium, Calcium, and Sodium Vapors. J. BARNES. (*Astrophys. Journ.*, xxxix, 370.)—Further experiments on the spectra of metallic vapors under the conditions given by an electrically-heated furnace, the metals being vaporized *in vacuo*. In magnesium one of the chief features is the strength of the line λ 4571, compared with its absence or weakness under other conditions. It is a well-marked sun-spot line. For calcium the chief affected line is 6573, which is noted by Hale and Adams to be one of the most strongly affected lines on the whole of the spot spectrum. The sodium lines in the furnace spectrum are very much intensified, with wings very wide and clear, just as is noted in these lines in sun-spot spectra. These observations suggest that the experimental conditions reproduced very nearly the physical conditions of density, temperature, and excitation which may exist in sun-spot vapors.

The Color of Illuminants. L. A. JONES. (*Am. Illum. Eng. Soc. Trans.*, ix, 687.)—Color analysis of the light emitted by various sources may be made by (*a*) the trichromatic or (*b*) the monochromatic method. The author has made a series of determinations by method (*b*), using the well-known Nutting colorimeter. He takes the light from the noon sun reflected from a block of magnesium carbonate as his standard of white light. The monochromatic light was obtained by means of a constant-deviation prism; the wave-length of this light can be adjusted by rotating a drum which is graduated in wave-lengths. Tables are given showing the values of the "per cent. white" and dominant hue for a large number of sources. In the case of glow lamps color analyses are made from the point at which the filament is just glowing up to the maximum current. The candle-power and the watts per candle are measured over the whole range. The precision obtainable in a single reading is of the order + 3 per cent. in the "per cent. white" reading, and + 0.5 $\mu\mu$ in the wave-length of a dominant hue. The author claims that this method offers a means of specifying the efficiency of a lamp in absolute terms, free from any arbitrary factors, such as color screens and filters. In the discussion H. E. Ives pointed out that for precision work (1) there must be a standard of white light; (2) we must be able to reproduce that white light at any time or place; (3) we must have some authorized method of measuring the brightness of the spectrum color against the white. He himself had previously suggested noon sunlight. He also referred to an instrument by which any spectrum energy-distribution, such as white light, can be produced at will, and to the difficulty of measuring the intensity of a white against a pure spectrum color. The author, in his reply, stated that color analyses of the acetylene flame have been made over a long period of time, using noon sun as a standard white, but no appreciable variation in the analyses has been found.

Standard Specifications for Cement. (*Year Book of Amer. Soc. Testing Materials,* 1914, 290.)—*General Conditions.*—All cement shall be inspected and at least twelve days allowed for inspection and testing. A bag of cement shall contain 94 pounds of cement net; and each barrel of Portland cement shall contain four and of natural cement three bags of above net weight. Cement failing to meet the seven-day requirements may be held pending the results of the twenty-eight-day tests before rejection. All tests shall be made in accordance with the methods of the American Society of Civil Engineers. Acceptance or rejection shall be based on the following requirements:

Natural cement is defined as the finely-pulverized product resulting from the calcination of an argillaceous limestone at a temperature only sufficient to expel the carbonic acid gas. *Fineness.*—Not more than ten per cent. by weight to be left on a No. 100 and not more than thirty per cent. on a No. 200 sieve. *Time of Setting.*—At least ten minutes for initial set and from thirty minutes to three hours for hard set. *Tensile Strength.*—The minimum requirements for briquettes one square inch in cross-section are given in the table: no retrogression in strength must be shown within the periods specified. *Constancy of Volume.*—Pats of neat cement about three inches in diameter, 0.5 inch thick in centre, and tapering to a thin edge, shall be kept in moist air for twenty-four hours, and subsequently shall remain firm and hard and show no signs of distortion, checking, cracking, or disintegration when kept in air at normal temperature or in water at about 70° F. (21° C.) for at least twenty-eight days.

Portland cement is defined as the finely-pulverized product resulting from the calcination to incipient fusion of an intimate mixture of properly-proportioned argillaceous and calcareous materials, and to which no addition greater than three per cent. has been made subsequent to calcination. *Specific Gravity.*—Not less than 3.10. If a sample fails to pass, a second test may be made on a sample ignited at a low red heat: the loss in weight on ignition shall not exceed four per cent. *Fineness.*—Not more than eight per cent. on a No. 100 and not more than twenty-five per cent. on a No. 200 sieve. *Time of Setting.*—At least thirty minutes for initial set and from one to ten hours for hard set. *Tensile Strength.*—See table: same conditions as for natural cement. *Constancy of Volume.*—Same as for natural cement, with the addition that a third pat is exposed in an atmosphere of steam, above boiling water, in a loosely closed vessel for five hours. *Sulphuric Acid and Magnesia.*—Not more than 1.75 per cent. SO_3 and not more than four per cent. MgO.

Age	Tensile strength of			
	Natural cement		Portland cement	
	Neat	Mixed with 3 parts of standard Ottawa sand	Neat	Mixed with 3 parts of standard Ottawa sand
	Pounds	*Pounds*	*Pounds*	*Pounds*
24 hours in moist air	75	...	175	...
7 days (1 in moist air, 6 in water)	150	50	500	200
28 days (1 in moist air, 27 in water)	250	125	600	275

Felspar as a Possible Source of American Potash. A. S. CUSHMAN and G. W. COGGESHALL. (*Amer. Inst. Chem. Eng.*, Dec. 2, 1914.)—In 1914 the United States of America imported potassium salts to the value of $15,000,000, including chloride of the value of $8,000,000. Most of this, including 85 per cent. of the chloride, was utilized in the fertilizing industry, and the remainder of the chloride was converted chiefly into hydroxide, carbonate, chlorate, and bichromate. Most of the American sources of potash, namely, the kelps, saline lakes and wells, and alunite deposits, are situated in the West, whereas the demand exists east of the Allegheny Mountains; and it is considered unlikely that the Panama Canal will enable Western potashes to compete with the European product. On the other hand, the great Appalachian felspar dikes are close to the centres of demand. In the process described, a mixture of ground felspar, 10 per cent. K_2O, and burnt limestone is formed into "clumps" by treatment with calcium chloride solution and heated in a rotary kiln, the fuel being oil or powdered coal. The red-hot product falls into lixiviating vats. The weaker vat liquors are used in a further operation, while the stronger ones are concentrated by spraying through the waste hot gases, whereby loss of potassium chloride by volatilization is also prevented. The product, after drying in a rotary drier which utilizes the hot waste gases of the limekiln, contains 70 to 80 per cent. KCl, 14 to 16 per cent. NaCl, and small amounts of calcium salts and moisture, as against 70 to 80 per cent. KCl in the imported "80 per cent. muriate." A high-grade product can be obtained by fractional crystallization. The general plant, in the main, resembles a Portland cement mill. The total cost of a plant to handle 300 tons of felspar per twenty-four hours is given at $100,000 for the general plant, with an additional $70,000 for the special equipment. The estimated total expenditure per day of $1488.90 is composed of $800 for raw materials, $554.60 for manufacturing operations, and $64.30 for charges, including interest and depreciation. Calculating on the basis of an 80 per cent. conversion of K_2O to KCl, the cost of the product amounts to $31.32 per ton, as against $37.50 for the normal price of the imported "80 per cent. muriate," which latter, however, is probably artificially controlled. No account is taken in these estimates of possible valuable by-products. Since all the requisite materials are available in this country, the authors consider that the United States of America might be rendered independent of foreign supplies.

Presence of Salt an Indication of Other Impurities in Boiler Water. (*Electr. World,* lxv, No. 2, 101.)—At one of the large generating stations in New York City, where salt water is employed to cool the condensers, the condensate is tested every hour to determine whether any salt is present. If any is found, it indicates that the condensers are leaking and must be immediately attended to or all of the boiler water will be contaminated. The test is also valuable in that it forewarns when additional feed-water compound may be required to precipitate impurities which are carried into the boilers along with the salt. Not only is the condensate tested, but also the boiler's contents. This, however, is done only once a day, as leakage of scale-forming compounds into the feed-water system is usually noted by the analysis of water from the condensers. The standard titration test of adding silver nitrate to the water is employed. This is much simpler than testing for the presence of other impurities. To remove scale-forming impurities from the water it is treated by the addition of sodium carbonate, and the precipitate is removed by blowing off the boilers when the fires are banked.

Chemiluminescence. S. MOELLER. (*Archiv. Pharm. Chem.*, xxi, 440.)—The appearance of light has been noted in several chemical reactions, notably in that of Grignard, when an ether solution of an alkyl halide reacts with magnesium dust. A red light is developed on mixing 35 c.c. of each of the following solutions: A 1 : 2 potassium carbonate solution, a 1 : 10 pyrogallol solution, and a 35 : 100 formaldehyde solution; then adding 50 c.c. of 30 : 100 hydrogen peroxide solution. Also phenylmagnesium bromide, in ether solution, develops an intense green light on contact with moist air. The effect is not, however, due to the moisture, but to oxidation. The luminescence is stronger in an atmosphere of pure oxygen than in other gases. Ether which has stood months over calcium chloride reacts well; some, but not all, specimens of official ether do so also. Chemiluminescence is observed with most organic magnesium compounds, and its intensity is directly proportional to the molecular weight of the halogen derivative.

Action of Acid Mine Water on the Insulation of Electric Conductors. H. H. CLARK and L. C. ILSLEY. (*U. S. Bureau of Mines, Techn. Paper 58.*)—Four different types of insulation were used in the tests: (1) Wire, 0.162 inch diameter, covered with eight layers of varnished cotton cambric, 0.146 inch thick, and one layer of cotton braid, 0.056 inch thick, saturated with a composition. (2) Wire, 0.325 inch diameter; rubber layer, 0.0925 inch thick, containing 30 per cent. Para; cotton tape, single layer; cotton braid, with waterproof finish, two layers, 0.035 and 0.033 inch thick. (3) Wire, 0.162 inch diameter; varnished cambric, 11 layers, 0.116 inch thick; cotton braid with weatherproof finish, two layers, 0.029 and 0.04 inch thick. (4) Lead-sheathed telephone cable, composed of five pairs of paper-covered wires, surrounded by lead 3/32 inch thick. The cables were sprinkled with 0.45 per cent. sulphuric acid or a 1.2 per cent. solution of ferrous sulphate in this acid three times daily for the first four weeks, once daily for ten weeks, twice daily for seventy-six weeks, and subsequently once daily, and, beginning eight months after the tests were started, the insulation resistance was measured at intervals over a period of two years. The rubber insulation showed no apparent deterioration, and the insulation resistance, although only about half the original, was still very good. The telephone cable also gave good results. The cambric-covered wires, (1) and (3), had practically lost their insulation, mainly through the penetration of the liquid between the layers.

Steel Coated with Copper. W. M. PAGE. (*U. S. Patent 1,125,158 of 1915.*)—Steel articles are provided with a coherent coating of magnetic iron oxide and are then dipped into molten copper until bubbling ceases.

INDEX TO VOL. CLXXIX.

ABBOTT, ROBERT R.: Modern steels and their heat treatment, 415
Acoustics, Architectural (Sabine), 1
Air-gap flux distribution in dynamo-electric generators (Still), 21
American engineer in China (Parsons), 381
Apparatus for measuring electrical conductivity above 1500° C. of vapors (Northrup), 337
Architectural acoustics (Sabine), 1
Atom, Modern views on the constitution of the (Eve), 269

BIRKINBINE, JOHN: Iron a factor in the world's progress, 471
Boiling-point of aqueous solutions of nitric acid (Creighton and Githens), 161
BOOK NOTICES:
  Autenrieth, William: Laboratory manual for the detection of poisons and powerful drugs, 255
  Gage, Simon Henry, and Henry Phelps: Optic projection, 256
  Hart, Richard N.: Leavening agents 502
  Horsburgh, E. M.: Modern instruments and methods of calculation, 364
  Iowa State University Bulletin No. 87, 364
  Leffmann, Henry: Examination of water, 503
  Smallwood, Julian C.: Mechanical laboratory methods, 254
  Vulté, Herman T.: Food industries, 108

Cast-iron manufacture, Recent developments in (Johnson), 59, 171
China, An American engineer in (Parsons), 381
COBLENTZ, W. W.: Glasses for protecting the eyes from infra-red rays, 579
Concrete structures, electrolysis in, Paints to prevent (Gardner), 313
CONNELL, WILLIAM H.: The organization, character of personnel, scope of work, and methods of operation and control of a large municipal highway department, 439
CORRESPONDENCE:
  The thunderstorm and its phenomena (Ferguson), 253
CREIGHTON, HENRY JERMAIN MAUDE, and JOHN HORACE GITHENS: On the boiling-point of aqueous solutions of nitric acid at different pressures (Part I), 161
CURRENT TOPICS, 94, 99, 100, 109, 110, 169, 170, 213, 214, 223, 224, 257, 258, 282, 311, 312, 336, 365, 366, 413, 414, 438, 469, 470, 495, 496, 504, 505, 558, 577, 578, 585, 586, 595, 596, 600, 614, 615, 696, 709, 710, 718, 730

DREW, E. C.: The ionizing potential of an X-ray tube, 697
Dynamo-electric generators, Air-gap flux distribution in (Still), 21

Electrical conductivity above 1500° C. of vapors, Methods, data, and new apparatus for measuring (Northrup), 337
Electrolysis in concrete structures, Paints to prevent (Gardner), 313
Enzymes, Behavior of, at low temperatures (Hepburn), 581
EVE, A. S.: Modern views on the constitution of the atom, 269

FERGUSON, OLIN J.: The thunderstorm and its phenomena (correspondence), 253
FRANKLIN INSTITUTE:
  Board of Managers, Report for 1913–14, 226
  Certificate of Merit. Award to George P. Vanier for his potash bulb, 248
  Edward Longstreth Medal. Award to Edward J. Dobbins for his daylight rods, 498

Edward Longstreth Medal. Award to George A. Wheeler for his escalator, 607
Endowment Committee, Report for 1913–14, 241
Elections and Resignations of Members Committee, Report for 1913–14, 235
Exhibitions Committee, Report for 1913–14, 239
Franklin Medal. Letter from Thomas Alva Edison, 720
Franklin Medal. Letter from H. Kamerlingh Onnes, 720
Instruction Committee. Report for 1913–14, 232
Joint meeting with Philadelphia Section, Illuminating Engineering Society, 497
Library Committee, Report for 1913–14, 227
Library notes, 103, 251, 361, 500, 610, 725
Meetings Committee, Report for 1913–14, 231
Membership notes, 102, 249, 360, 499, 609, 721
Museums Committee, Report 1913–14, 230
Publications Committee, Report for 1913–14, 238
School of Mechanic Arts, Address to graduating class (Hoadley), 587
School of Mechanic Arts, Annual report of the director, 601
Science and the Arts Committee Proceedings: December 2, 1914, 101; January 6, 1915, 247; February 3, 1915, 359; March 3, 1915, 498; April 7, 1915, 606; May 5, 1915, 720
Science and the Arts Committee, Report for 1913–14, 242
Sectional Arrangements Committee, Report for 1913–14, 239
Sections, proceedings of meetings: 102, 248, 359, 498, 607
Standing Committees, 1915, 357
Stated meetings, proceedings: December 16, 1914, 101; January 20, 1915, 225; February 17, 1915, 357; March 17, 1915, 497; April 21, 1915, 601; May 19, 1915, 719
Stocks and Finance Committee, Report for 1913–14, 236

FRANKLIN, WILLIAM S.: A method for calculating that part of the recoil momentum of a gun which is due to the action of the gases after the projectile leaves the muzzle, 559

GARDNER, HENRY A.: Paints to prevent electrolysis in concrete structures, 313
  A study of some curious painting phenomena, 681

GITHENS, JOHN HORACE, and HENRY JERMAIN MAUDE CREIGHTON: On the boiling-point of aqueous solutions of nitric acid at different pressures (Part I), 161

Glasses for protecting the eyes from infra-red rays (Coblentz), 579

Gunnery. A method for calculating that part of the recoil momentum of a gun which is due to the action of the gases after the projectile leaves the muzzle (Franklin), 559

HADFIELD, SIR ROBERT A.: Sound steel for rails and structural purposes, 119
  Sound steels for rails and structural purposes (Second communication), 663

Heat treatment of steel (Abbott), 415

HEPBURN, JOSEPH SAMUEL: The behavior of enzymes at low temperatures, 581

High temperature investigation and a study of metallic conduction (Northrup), 621

Highways. The organization, character of personnel, scope of work, and methods of operation and control of a large municipal highway department (Connell), 439

HOADLEY, GEORGE A.: Address to graduating class, Franklin Institute School of Mechanic Arts, 587

Infra-red rays, Glasses for protecting the eyes from (Coblentz), 579

Ionizing potential of an X-ray tube (Drew), 697

Iron a factor in the world's progress (Birkinbine), 471

JOHN SCOTT MEDAL:
  Award to Charles Edward Guillaume for his alloy invar, 247
  Award to Herbert Alfred Humphrey and Alberto Cerasoli for the Humphrey pump, 606

Johnson, J. E., Jr.: Recent developments in cast-iron manufacture, 59, 171

Main line electrification, Conditions affecting the success of (Murray), 513
Mees, C. E. Kenneth: The physics of the photographic process, 141
Metallic conduction, A study of (Northrup), 621
Municipal highway department, The organization, character of personnel, scope of work, and methods of operation and control of a large (Connell), 439
Murray, W. S.: Conditions affecting the success of main line electrification, 513

Naval warfare, The modern submarine in (Robinson), 283
Nitric acid, On the boiling-point of aqueous solutions of (Creighton and Githens), 161
Northrup, Edwin F.: High temperature investigation and a study of metallic conduction, 621
Northrup, Edwin F.: Methods, data, and new apparatus for measuring electrical conductivity above 1500° C. of vapors at normal pressures, 337

Painting, Artistic, and the old masters (Toch), 47
Painting phenomena, A study of some curious (Gardner), 681
Paints to prevent electrolysis in concrete structures (Gardner), 313
Parsons, William Barclay: An American engineer in China, 381
Photographic process, The physics of the (Mees), 141
Physics of the photographic process (Mees), 141
Projectiles. A method for calculating that part of the recoil momentum of a gun which is due to the action of the gases after the projectile leaves the muzzle (Franklin), 559
Publications received, 108, 257, 365, 503, 613, 728

Railroad rails, Sound steel for (Hadfield), 119, 663
Railroads. Electrification. Conditions affecting the success of main line electrification (Murray), 513
Recoil momentum of a gun, A method for calculating that part of the, which is due to the action of the gases after the projectile leaves the muzzle (Franklin), 559
Robinson, R. H. M.: The modern submarine in naval warfare, 283

Sabine, Wallace C.: Architectural acoustics, 1
Steel, Sound, for rails and structural purposes (Hadfield), 119, 663
Steels and their heat treatment (Abbott), 415
Still, Alfred: Air-gap flux distribution in dynamo-electric generators, 21
Submarine, The modern, in naval warfare (Robinson), 283

Thunderstorm and its phenomena (Ferguson), 253
Toch, Maximilian: Artistic painting and the old masters, 47

U. S. Bureau of Standards Notes, 95, 215, 353, 489, 597, 711

Vapors, electrical conductivity of, methods, data, and new apparatus for measuring (Northrup), 337

X-ray tube, The ionizing potential of an (Drew), 697

PRESS OF
J. B. LIPPINCOTT COMPANY
PHILADELPHIA

JOURNAL OF

THE FRANKLIN INSTITUTE

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS

EDITED BY
R. B. OWENS, E.E., M.A., D.Sc., F.R.S.C.

ASSOCIATE EDITORS:

BRIG. GEN. JAMES ALLEN
WILDER D. BANCROFT, PH.D.
JOHN J. CARTY, D. SC.
A. S. CUSHMAN, PH.D.
LOUIS DUNCAN, PH.D.
A. S. EVE, D.SC.
W. J. HUMPHREYS, PH.D.
HARRY C. JONES, PH.D.
HARRY F. KELLER, PH.D.
GAETANO LANZA, C.E.
RALPH MODJESKI, D.ENG.
L. A. OSBORNE, M.E.
ALBERT SAUVEUR, B.S.
EDGAR F. SMITH, PH.D.
LT. COL. GEO. O. SQUIER, PH.D.
C. P. STEINMETZ, PH.D.
S. W. STRATTON, SC.D.
ADMIRAL D. W. TAYLOR
S. M. VAUCLAIN, SC.D.
R. S. WOODWARD, PH.D.
A. F. ZAHM, PH.D.

COMMITTEE ON PUBLICATIONS:
LOUIS E. LEVY, CHAIRMAN
GEORGE A. HOADLEY
W. C. L. EGLIN
GEO. D. ROSENGARTEN
E. H. SANBORN

VOL. CLXXX.—Nos. 1075–1080
(90th YEAR)

JULY-DECEMBER, 1915

PHILADELPHIA
Published by the Institute, at the Hall, 15 South Seventh Street
1915

JOURNAL
OF
THE FRANKLIN INSTITUTE

DEVOTED TO SCIENCE AND THE MECHANIC ARTS

VOL. CLXXX JULY, 1915 No. 1

CONTROL AND PROTECTION OF ELECTRIC SYSTEMS.*

BY

CHARLES PROTEUS STEINMETZ, M.A., Ph.D.,

Chief Consulting Engineer, General Electric Company.
Member of the Institute

WHEN the first commercial electric circuit issued from a station the problem of control and of protection arose. It was a simple problem at first: an ammeter and voltmeter to measure current and voltage; a knife-blade switch to send the current into the desired path, or withdraw it; the fuse to open the circuit in emergencies, and if the wires became crossed and fuse and switch failed, generator and engines stopped, and not much harm was done.

With the extension of the circuits into the suburbs some lightning troubles were felt and led to the introduction of lightning arresters—in the early days based mainly on hope and trust in Providence rather, as very little was known of lightning phenomena.

Since these days, less than a generation ago, enormous changes have taken place, and the electric systems have increased in size, in voltage, and in extension.

Where 100-horse-power machines were large once, now steam turbine alternators of 40,000 horse-power and more are in com-

---

*Presented at the joint meeting of the Electrical Section and the Philadelphia Section, American Institute of Electrical Engineers, held April 15, 1915.

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

Copyright, 1915, by THE FRANKLIN INSTITUTE.

mercial operation. The steam engine has made room for the steam turbine, and the steam turbine does not stop when the wires are crossed and a short circuit occurs, and the momentum of the turbine disks, revolving at velocities of 300 to 400 miles per hour, can supply ample energy for the destruction of any part of the system.

Feeders of 10,000 horse-power or more, generators of 40,000 horse-power have to be controlled by switching: an attempt to open such a circuit by the knife-blade switch of old would lead to the destruction of the switch—and probably its operator.

Instead of small machines operating separately on independent circuits, huge generators now feed in parallel into the system of busbars, on which is concentrated all the power of the station or the group of stations which are tied together. Numerous stations and systems of interconnected stations of 100,000 to a quarter million horse-power and over are in operation, and the half-million horse-power mark has been reached.

Anywhere on the busbars of the station or in the feeders near the station there is available, destructively in case of an accident, as a short circuit, not only the entire power of the station, of perhaps half a million horse-power, but the far greater power which the station generators can give momentarily.

Short-circuit currents of forty to fifty times normal full-load current may momentarily flow from some turbo-alternators, representing ten and more times full-load power.

Such a station, or group of closely interconnected stations, of half a million horse-power full-load capacity, may momentarily send into a short circuit at the busbars over five million horse-power. This is the power of Niagara: for Niagara is estimated variously at from 5,000,000 to 15,000,000 horse-power.

It is obvious that no switch or circuit breaker can be built to safely open such power, to suddenly stop Niagara, especially when considering that many hundreds of feeders issue from the busbars, that in any one of these feeders a short circuit in the cable may let loose the power of the entire system, and every feeder thus requires such a circuit breaker.

With half a million horse-power station capacity, a momentary overload capacity ten times as high, assuming that we could build a circuit breaker to open this short-circuit power as quickly as in three to four cycles, or one-eighth second: this would require to dissipate in the circuit breaker the energy of over 200,000,000 foot-pounds—the destructive energy of 1000 tons dropping from a height of 100 feet. This is about the energy of a projectile of 2000 pounds weight leaving the cannon at the velocity of 2500 feet per second. It is the destructive energy of two heavy railway trains, of 400 tons each, going at sixty miles per hour, and meeting in head-on collision. It is the energy of the explosion of thirty pounds of dynamite.

Equally great has been the increase of voltage: where once 2000 volts were high-voltage distribution, in circuits of a few miles length, now circuits of hundreds of miles length are in operation at voltages of 100,000 to 150,000. Such voltages jump toward any object for over a foot distance, and will maintain arcs of practically unlimited distance; that is, with 100,000 volts and practically unlimited power back of it, an arc can extend for hundreds of feet. Thus no simple switch will open such voltages under power.

Transmission systems at high voltages have been interconnected with each other into networks, which spread and extend, and already to-day often represent thousands of miles of interconnected high-voltage lines, covering tens of thousands of square miles, and picking up every lightning, every atmospheric disturbance within this entire area.

Thus the lightning protection also has become a far larger problem than in the small circuits of old.

But far greater than the energy of any lightning stroke is the energy stored as magnetic field surrounding the conductors, as dielectric field radiating from the conductors of these big transmission systems, and if this internal energy of the system is set surging, its effects are far more destructive than those of lightning, and the effects may not be merely momentary, as those of lightning, but continual, as machine energy continually replaces the stored internal energy, which causes the destructive surge.

And, in addition hereto, far greater reliability and continuity of service is to-day demanded from the electric systems than was in the early days, and that at a lower cost of electric energy, and it must be remembered that, with the increasing cost of living, electricity is one of the few commodities which has steadily decreased in price.

The foremost problem of control of electric systems thus is that of controlling enormous powers; the foremost problem of protection is that against self-destruction by its own power.

Current and voltage have grown beyond the values for which instruments can be built, and *current transformers* and *voltmeter transformers* are interposed between the circuit and the instruments measuring it. With the general introduction of parallel operation, *power factor indicators* are required to insure the division of load without excessive waste currents; *frequency indicators* and *synchronizing devices* to safely connect machines into the system.

With hundreds of feeders radiating from the generating station, the office of the load dispatcher has become essential, and the necessity of keeping exact records of all operations and of all accidents and incidents is of the greatest importance. Automatic recording devices thus have been developed, as the *multi-recorder,* to record, within fractional seconds, all important events, as opening and closing of switches, starting and stopping of generators, surges, lightning disturbances, etc. Such automatic devices afford a valuable check on the operating staff, but more important still is their record in emergencies, where a number of things happen almost at once, where the attention of the operators is detracted from accurate observation by the necessity of action, and the record thus could be made only afterwards from memory, which is not very accurate in such a period of excitement. It is just in such abnormal conditions where the most complete and accurate record is of greatest importance, to enable the engineers to determine with certainty what happened and why it happened, so as to take steps to guard against its recurrence.

Oil circuit breakers have been developed, which can safely and without disturbance close and open the feeder circuits of over 10,000 horse-power, the generator circuits of 40,000 horse-power and more, with an ample margin of overload capacity. In these the circuit is opened under oil with such mechanical arrangement of contacts and oil vessel that in the moment of circuit opening the current is extinguished at the end of a half wave by the rapid expansion and chilling of the oil vapor which is produced by the opening arc, and which in the first moment is under high compression, due to the momentum of the oil, which has to be set in motion.

The most serious danger, in the growth of electric systems, was, however, the possibility of self-destruction by the power let loose under short circuit, and there were anxious years for the operators and managers of these large electric systems before the industry devised the means of safely controlling unlimited power. More than once, when a serious short circuit occurred and a disaster was averted only by luck, the system was cut into two or three sections and these operated independently, to limit the power. But when months passed without further accidents, invariably, due to the requirements of economy and reliability of operation, the sections came together again and parallel operation of the entire system was restored.

This, the most serious problem of the high-power electric system, was solved by the development of the *power limiting reactances.*

In the generator leads, between generators and busbars, are inserted reactances, capable of standing enormous overloads, of a size sufficiently small not to interfere with the normal flow of power, at full load or any overload which the generator may be called upon, but large enough to materially limit the generator current and power at short circuit. Usually the *generator reactances* limit the momentary short-circuit current to about ten to twelve times full-load current; that is, the momentary short-circuit power to about two and one-half times full-load power. This solved the problem for medium-sized stations. Thus in a 60,000-horse-power station, instead of a possible short-circuit power of over half a million horse-power, the power is limited to 150,000 horse-power.

However, even with generator reactances, with increasing size of station, the power which may be let loose under short circuit becomes large beyond control; with a 400,000-horse-power station, with generator power limiting reactances, a million horse-power may still be concentrated at a short circuit.

Busbar reactances then were introduced; that is, the busbars divided into sections by reactances sufficiently small not to interfere with the interchange of power along the busbars, and thereby retaining the advantage of parallel operation, but large enough to limit the flow of power, which, in case of a short circuit on one busbar section, can flow into it from the adjoining sections.

By such reactances in the busbars and in the tie feeders between the stations, the system is divided into sections of about 60,000 horse-power each. A short circuit then can seriously involve one busbar section only, and the destructive power of a short circuit is limited to that of one section, plus the limited power which can flow from the two adjoining sections, a total of 150,000 to 200,000 horse-power, and this is within the emergency limit of the modern oil circuit breaker of moderate size. It still represents a terrific energy, nearly 10,000,000 foot-pounds, and is a severe strain on the circuit breaker.

These busbar reactances permit an unlimited extension of the system, and the short circuit on a section of a half-million-horse-power system is no more severe than a short circuit on a 100,000-horse-power system, and there is now no limitation to the future increase to electric systems of many millions of horse-power capacity, operating in parallel on one set of busbars.

With hundreds of feeders radiating from the busbars, the probability of a short circuit in feeders is far greater than in the busbars, and a material advantage, therefore, is given by *feeder reactances;* that is, reactance interposed between the feeder or a group of feeders and the busbars, so that a short circuit in the feeder is still more limited than a short circuit in the busbars.

By the development of generator reactances, busbar reactances, and feeder reactance, the problem of the power control of large systems for protection against self-destruction by short circuit has been solved and unlimited extension of systems without any increase of danger has been made possible, and experience has shown that after the introduction of such power-limiting reactances dead short circuits have occurred at the busbars of very large systems without even interfering with the operation of most of the synchronous apparatus on the system.

Not all three classes of reactances are always necessary: in systems of moderate size busbar reactances may not yet be needed. In low-head water-power plants, with slow-speed multipolar alternators of inherently limited short-circuit current, generator reactances may be unnecessary and only busbar reactances required. Such, for instance, is the case at the Keokuk plant on the Mississippi River. Again, with a perfect system of generator and busbar reactances, feeder reactances may be dispensed with—though they are even then an advantage.

In high-voltage transmission networks, even of very high power, power-limiting reactances sometimes may not be required or less essential. With a considerable number of medium-sized water-power plants feeding into a transmission system, the power of each individual generating station may not be sufficient to give destructive values under short circuit, and the impedance of the lines between the generating stations may be sufficient to limit the power which can feed into the short circuit at one station. In transmission networks, therefore, power-limiting reactances are necessary only in very large generating stations, as the Keokuk station, or where several fairly large stations are close together, and also, as generator reactances, in turbo-alternators connected into the system as steam reserve.

To cut off a disabled line or feeder with the voltages and powers of our modern systems is beyond the capacity of the fuse or simple blade switch, and automatic oil circuit breakers are generally used. However, the problem has become more difficult by the increasing demand for reliability and continuity of service.

The two main sources of troubles in lines and cables are *grounds* and *short circuits* between phases. In transmission lines a ground on one phase is the most frequent trouble, and short circuits are rare except in lines in which the design was faulty, or reliability had been sacrificed to cheapness, and the spacing between conductors chosen too small, so that they swing together during wind storms, etc. A short circuit is far more serious than a ground, as in the former the current is limited only by the generator capacity, while with a ground the current has no return—except if the neutral is grounded, and then over the resistance of the neutral—and the current, and with it the shock on the system, therefore is very much less, especially if safeguards against the occurrence of high frequency by *arcing grounds* are installed. In a well-designed transmission line a short circuit usually occurs only as the result of two simultaneous grounds. A ground on one conductor, however, raises the voltage against ground, of the other two phases, from the Y voltage to the delta voltage of the system, and thereby increases the strain on the insulation of the other two phases. It thus either introduces the danger of a second ground, causing a short circuit, or requires a higher grade of insulation.

This has led to two methods of operation of transmission systems. Either the neutral of the transformers is grounded, frequently through a resistance, where the resistance of the ground is not high enough to limit the current. Then a ground on one phase is a partial short circuit to the neutral, causes a large current to flow, and thereby opens the automatic circuit breakers and cuts off the circuit before the ground has developed to a short circuit. However, this method, the "*grounded Y system*," means a shutdown at every ground, every flashover of an insulator by lightning, etc. Or the neutral of the system is not grounded, the insulation of the circuit made good enough to safely stand the increased strain put on it by a ground on one phase, and by an *arcing ground suppressor,* etc., care taken not to continue an arcing ground—leading to high-frequency disturbances—but convert it into a metallic ground. In this case, the "*isolated delta*" *system,* service can be maintained on the circuit, even if one phase grounds, until arrangements are made to take care of the load, or the fault found and remedied, and the continuity of service thus is not interfered with. However, the cost of line construction is higher, due to the better insulation required. The relation between grounded Y and isolated delta thus is that of cheapness *versus* reliability and continuity of operation, and, as a rule, we find grounded Y systems where lowest cost of development is considered essential and occasional interruption of service not considered objectionable, while the isolated delta is generally preferred in systems in which reliability and continuity of service are considered as of first importance, such as in the extension across the country of the great Metropolitan Edison Systems—systems which are proud of their record that the voltage has not been off their busbars for ten years or more.

Different are the conditions in underground cable systems. In a cable the three conductors are so close together that a ground on one conductor quickly reaches the other conductors and becomes a short circuit. A grounded cable, therefore, cannot be kept in service, but has to be cut out as promptly as possible. In these systems it therefore is customary to ground the neutral through a resistance sufficiently low, in case of a ground on one conductor of a cable, to allow sufficient current to flow to open the circuit breaker and cut off the cable, but sufficiently high not to give a severe shock on the system. Or, where grounding of the neutral is considered undesirable, an arrangement of relays is made to give the same effect. With underground cables such cutting off of a disabled feeder does not interfere with the continuity of service, as a number of feeder cables are always used in multiple for every important substation.

However, the problem of cutting off a disabled feeder by the operation of the circuit breaker, due to the large current taken by the grounded feeder, is not so simple. Assuming that three cables feed in multiple into a substation, and one of these feeders grounds: a large current then flows from the generating station into this cable to ground, and the circuit breaker at the generator end of this feeder opens. This, however, does not stop the current rush, but a large current still flows through the damaged cables into the ground, coming back from the substation, and flows to the substation from the generating station through the two parallel feeders, which are undamaged; that is, short-circuit current feeds back through these two cables over the substation, and these two cables also open their overload circuit breakers, cutting off and thereby shutting down the substation. If the substation is connected by tie feeders to adjoining substations, current feeds back into the faulty cable over these tie feeders from adjoining substations, and these tie feeders, and the cables feeding the adjoining substations from the generating station, open their circuit breakers by overload, and in this manner a ground in one cable may shut down a number of substations, possibly the entire system. *Time-limit devices* in the circuit breakers are insufficient to protect against such extended shutdowns resulting from a single fault in a cable. A permanent time limit is not permissible in large systems, as with a dead short circuit the circuit breakers must open instantly before extensive damage is done by the large power of the short circuit. Therefore so-called "*inverse time-limit*" circuit breakers are generally used; that is, circuit breakers in which the time limit of their operation decreases with increasing overload. Such circuit breakers would first cut off the cable carrying the greatest excess current,—that is, the faulty cable,—and then those of less excess current; but, as with the cutting off of the faulty cable—at both ends—the excess current stops, other cables should not be interfered with. However, the inverse time-limit circuit breaker necessarily must be practically instantaneous under short circuit, and therefore, while the time limit discriminates between 100 per cent. or 200 per cent. or 300 per cent. overload, it cannot discriminate between short circuits of various severity; that is, not only the faulty cable, but its parallel undamaged cable, and the tie cables to other substations, etc., would open, and, while the extent of the shutdown would be somewhat limited, it is still far beyond the extent permitted by reliability of service.

Thus devices become necessary to select a disabled feeder and cut it out without cutting off its parallel feeders or the tie feeders to the substation served by the faulty feeder, regardless of what excess currents these may carry. This is a problem which has not yet been completely solved.

As the result, in general in high-power systems of high standard of reliability the radial system of substation supply is used; that is, each substation is fed by a separate set of cables, and the substations are not interconnected into a network by a system of tie feeders. This radial system, however, is materially less economical in feeder copper than the interconnected network, since the radial system requires for each substation a feeder capacity equal to the maximum power demand of the individual substation, while in the network, by cross-feeding between the substations, the feeder capacity is reduced to that required by the average maximum demand of the substations.

To avoid a shutdown of the substation by a fault in one of its feeders, the different feeders of the same substation are not connected in parallel in the substation, but feed separate translating devices, as transformers and converters, and are paralleled in the substation only on the secondary side of transformer or converter. In case of a faulty feeder, the current feeding back into the fault over the other feeders of the same substation, therefore, has to pass through two sets of translating devices, and this limits it sufficiently to allow the time limit relay of the circuit breakers to operate and cut out the faulty feeder without opening the other feeders; that is, without shutting down the substation.

However, the economic disadvantage of the radical system remains, and an effective *selective feeder relay,* which could be relied upon to pick out the faulty feeder and no other, would offer material advantages.

Such a selective device is afforded by the use of *pilot cables.* Each cable or feeder is duplicated by a smaller low-voltage, three-phase cable, which joins the secondaries of current transformers connected into the two ends of the main cable. If the main cable is undamaged, the same current comes out of it as flows into it, and the connections to the pilot cable are such that in this case the secondary currents would be in opposition; that is, neutralize each other. If, however, the main cable grounds, current flows into it from both sides, the secondary currents in the pilot cable then add, and the current flowing in the pilot cable operates the relay which opens the circuit breaker. This arrangement is very perfect in operation, capable of cutting out the damaged cable, whether feeder cable or tie cable, without interfering with any other cable, but it has the formidable disadvantage of doubling the number of cables required in the system, and, while the pilot cables are small and of low voltage, they occupy room in the underground ducts which carry the electric circuits in American cities. Thus this method of control by pilot cable is, due to its high cost of installation, very little used in this country.

Another method is that of the "*split conductor*" cable. Every cable conductor is made of two parts, of which the one surrounds the other concentrically, with some insulation between them. Normally there is no potential difference between the inner and the outer half of the conductor, as they are connected with each other at the ends of the cable. If, however, a ground occurs on the cable, this ground can at first reach only the outer half of the conductor, and a potential difference and current appears between the inner and outer half of the conductor and operates the circuit breakers, through a relay connected between the two halves of the conductor, at either end of the cable.

This method also works very satisfactorily, but has the same economic disadvantage, though to a lesser degree than the method of pilot cables, in that the split conductor cable is materially larger and more expensive than the standard cable. It is therefore used to a limited extent only.

The usual method of taking care of the problem, at least in most cases, is by the so-called "*reverse power relay,*" also wrongly called "reverse current relay."

When a cable grounds, the current at its end reverses; that is, flows into the cable ("feeding back") instead of coming out of it. However, this reversal of current by itself can do nothing, as it is an alternating current, and as such has no direction of its own, but only a relative direction to other alternating waves, as that of the voltage. Installing then a wattmeter relay at the end of the cable,—that is, a relay operated by the action of two coils upon each other, the one coil energized by the current, the other by the voltage: if the current reverses, the voltage remaining the same, the pull of the relay reverses, and thereby closes the operating circuit, which opens the circuit breaker which disconnects the cable.

Such reverse power relay operates perfectly so long as there is any voltage for the reverse current to act upon. If, however, a short circuit occurs at or close to the substation, the voltage vanishes, and with it the reverse power relay looses its pull. To guard against this, the installation of reactances is recommended between cables and substations to give a sufficient voltage drop to operate the relay. However, this is an additional complication.

The reverse power relay is not adapted to guard tie feeders between stations, as in these the current reverses in direction with the change of the distribution of load between the substations.

Thus the reverse power relay does not make the operation of interconnected networks of substations possible, but in the radial system of operation, which is generally used, it is the only device which is generally available economically, and is very satisfactory, with the only exception—which must be realized—that it cannot operate where there is no voltage left.

In overhead transmission systems and networks the problems of selectivity are essentially the same as in underground cable systems, except that in interconnected networks of distributed generating power the high impedance of the lines often gives an automatic partial selectivity, which cannot exist with the low impedance of cable systems.

Interference by *lightning,* with high-potential transmission lines, has rather decreased with increasing line voltage, and this is very fortunate when considering the enormous extent of these systems and the resulting certainty of lightning effects. In the present high-potential transmission lines voltages have been reached comparable with the voltage of lightning disturbances; possibly not with the voltage of the direct lightning stroke—but direct strokes into lines are rare—but few lightning-induced voltages reach beyond the insulation strength of modern high-voltage lines. In 100,000-volt lines the insulators are tested for one minute at 200,000 to 250,000 volts, and stand momentarily, for the very short time of lightning, over half a million volts.

Thus it is rare that lightning flashes over or punctures the suspension insulators of our very high-voltage transmission systems. A flashover, with the grounded Y system, shuts down the circuit, often without any damage, while with the isolated delta system it may not even shut down the circuit, but is taken care of by the protective device against flashovers, the arcing ground suppressor in the station. Most lightning voltages incapable of destroying the line insulation run along the line until their energy is dissipated or they reach a station, and there they often do serious damage. The most important problem of lightning protection thus has become the rapid damping out of line disturbances caused by lightning, so as to make them harmless before they reach the station. The most effective method heretofore is the overhead ground wire. By its screening effect it lowers the voltage which lightning can induce in the line, but far more important is its powerful damping effect on the line disturbance, the travelling wave caused by lightning, which runs towards the station. As short-circuited secondary to the line wire, the ground wire absorbs and dissipates in its resistance the energy of the travelling wave, and causes it to die out at a rate several times more rapid than is the case in a line which is not protected by ground wire.

Far more destructive than the energy of lightning may be the *internal energy* of the system. While a lightning stroke may amount to millions of horse-power, at a duration of a millionth of a second, this means only thousands of foot-pounds. In a transmission network of thousands of miles extent a surge of the system may amount to many thousands of horse-power. But even a surge of a hundred horse-power only is liable to be very destructive, as it may be continual, the generator power continually replenishing the surge energy, and a hundred horse-power, during one hour, means 200,000,000 foot-pounds.

Thus the foremost problem is again the protection of the system against destruction by its internal energy, and lightning is dangerous mainly by letting loose the internal energy.

Against damage by breakdown to ground, by overvoltages, effective and complete protection is given by the *aluminum cell lightning arrester,* so that the problem of overvoltage protection resolves into the economic question, how far the cost of lightning arresters is warranted by the elimination of the danger of breakdown to ground.

Impulses, high-frequency oscillations, and stationary waves are the most common other dangers.

An *impulse* is an electrical effect in which voltage and current rise rapidly—with a "steep wave front"—and then gradually taper down and die out. Such impulses are produced by switching operation, by flash over the insulators, by induction from lightning flashes, etc. The danger from impulse voltages lies in the local piling up of voltage due to its steep wave front. Thus, for instance, when a switch is closed and 100,000 volts put onto a line at the moment of closing the switch, 100,000 volts suddenly appear in the line at the switch, while perhaps five feet away the line voltage is still zero. Gradually—with the velocity of light, or 188,000 miles per second—the voltage spreads over the line as an impulse. Suppose now such impulse reaches the terminals of a transformer near the source of the impulse, where its wave front is still very steep. When the full impulse voltage reaches the first transformer turn the second transformer turn is still at zero voltage, and the full voltage of 100,000 comes on the insulation between the first two turns. While the transformer winding is insulated to stand 200,000 volts to ground for one minute, and momentarily still much higher voltage, normally the voltage between adjacent turns may be only ten volts, and with all the extra insulation between the end turns, even if we make this insulation to stand 1000 times the voltage to which it is normally exposed, it would be far below standing 100,000 volts. Thus the danger from impulses is that they produce voltages across small parts of the circuit, single turns or coils, which are often many thousand times the normal voltage existing in this part of the circuit; thus they may be far below the total circuit voltage, and thus would not discharge over the overvoltage protective devices or "lightning arresters."

Fortunately such steep waves fronts rapidly flatten out in the progress of the wave along the circuit, so that their danger is largely limited to the immediate neighborhood of the origin of the impulse.

Assuming now that we would, by a condenser in shunt to the circuit, bypass the energy of the impulse for only one-millionth of a second. During one-millionth of a second the impulse travels about 1000 feet, and such a very small condenser would flatten the wave front to 1000 feet length. With such a flattened wave of 1000 feet front, before full voltage appears at the transformer terminals, the beginning of the impulse is passed over ten or more turns, and the impulse voltage thus distributes over the insulation of a number of turns, and no difficulty exists to give the end turns an extra insulation sufficient to stand the voltage.

The foremost cases of high-frequency oscillations are spark discharges from the line, arcing grounds, etc. Their danger also is the piling up of voltage in reactive devices, such as current transformers, end turns of power transformers, etc. While a current transformer may take only a few volts at the normal frequency of sixty cycles, at 10,000 times this frequency it would take 10,000 times the voltage, and then break down between turns and between terminals. Inductance to reflect the high-frequency oscillation back into the line—which can stand it—with shunted capacity, and a non-inductive or, preferably, a capacity bipath to the inductive device such as the aluminum cell, offers protection against the danger from high-frequency oscillations. The best guard against interference by high-frequency oscillations is, however, to avoid all causes which may produce them, and the foremost cause is the arc. Thus arcs, arcing grounds, spark discharges, open-air switches, etc., should be carefully avoided in transmission systems, as introducing the dangers of high-frequency disturbances. This is to a large extent a designing problem.

In apparatus capable of electric oscillation,—that is, apparatus of high inductance, considerable capacity, but very low energy losses, such as high-potential transformer windings,—under certain conditions *stationary waves* may occur; that is, high-frequency impulses or oscillations, coming from the outside, built up by resonance to higher and higher voltages. Such stationary high-frequency waves are extremely destructive, as their energy is practically unlimited; is given by the low-frequency power of the system. Their frequencies usually are fairly low, between 10,000 and 100,000 cycles, and therefore it is more difficult to deal with them than with the oscillations of many hundred thousands or millions of cycles.

The best protection against them is not to allow them to build up. This is done by designing the apparatus so as to give the least ability to stationary oscillations, and by dissipating their energy, and thereby limiting their voltage, by shunted resistance. To avoid the excessive waste of power in such shunted dissipating resistances, a condenser of moderate capacity is connected in series with them. Such condenser practically cuts off the flow of power at the low machine frequency, but permits the flow of large currents through them into the dissipating resistance at the much higher frequencies of the standing waves.

In considering the protection of modern electrical systems it must be realized that the various sources and kinds of interference or danger require correspondingly different protective devices: it would be just as unreasonable to expect a standard type of " lightning arrester " to protect an electric system against all possible troubles as it would be to call for a single-standard " safety device " which would protect a railway train against all possible dangers, from a broken rail or a washout of the roadbed to a collision or a boiler explosion.

The Use of Copper Sulphate in the Purification of Swimming Pools. STANLEY JUDSON THOMAS. (*Journal of Industrial Chemistry,* vol. 7, No. 6.)—Within the past two or three years numerous articles have been written relating to the sanitary conditions of indoor swimming pools. One fact is emphasized by all authorities: that the danger of transmission of zymotic disease through the swimming pool is *real.* There is no doubt that hypochlorite of lime, which has been recommended as a precautionary treatment of public water supplies, is without a peer. It has been shown that 2.5 parts per million of hypochlorite of lime purifies the water shortly after its introduction into the pool, but it soon loses its germicidal properties. To add 2.5 parts per million of " hypochlorite " every day would probably solve the problem from a bacteriological standpoint, but the odor would be too offensive for this form of treatment to be considered. The idea was conceived and acted upon of using a small amount of copper sulphate. The result of using 0.4 part per million of copper sulphate proved very satisfactory. From a comparative study and tests of the two methods of sterilization, the advantages of copper sulphate over hypochlorite of lime may be summarized as follows: (1) It is more effective, because it does not undergo chemical change readily. (2) It is not irritating to the eyes and mucous membrane, as is " hypochlorite," if the latter is used in germicidal quantities. (3) It is cheaper. (4) It has no odor. If all other conditions were equal, this last fact alone would prove its great advantage over " hypochlorite."

BIOCHEMICAL AND ENGINEERING ASPECTS OF SANITARY WATER SUPPLY.*

BY

GEORGE W. FULLER, C.E.,
Consulting Hydraulic and Sanitary Engineer, New York, N. Y.
Member of the Institute.

This topic is a very broad one. In fact, some difficulty has been experienced in reaching a conclusion as to which particular aspects of this topic these remarks should be directed.

"Biochemical" is not a very precise term. It is used differently by different persons. It is proposed to-night to speak more particularly of the biological rather than the chemical phases of this broad field which deals with the sanitary features of public water supplies. Reference will be made especially to means of measuring the sanitary quality of water supply through biological methods, and then of the accomplishments upon the public health of modern engineering works to conserve or improve the quality of water. The engineering works themselves will be scarcely touched upon.

While the main theme of this talk will be means of measuring the sanitary quality of public water supplies, both through laboratory procedures and the study of vital statistics, attention will be directed to some striking instances where it is proved that public water supplies are not wholly to blame for the prevalence of diseases generally associated with the public water supply. Other sanitary conditions are involved, and, as our knowledge of vital statistics and of modes of transmission of disease becomes more complete, it is shown that the city sanitarians have duties to attend to which in earlier years were assumed to belong to those who had charge of public water supplies.

This is a particularly apt time at which to speak on this subject. During the past week the United States Treasury Department has published a report of a Commission of Expert Sanitarians to specify bacteriological standards for drinking waters to be supplied to the public by common carriers in interstate commerce. That this task has not been an easy one is shown by the fact that it has required nearly two years of deliberations to formulate a six- or seven-page report.

---

* Based on a paper presented at the meeting of the Mechanical and Engineering Section held November 12, 1914. Manuscript received March 24, 1915.

Another feature of importance in the current developments of sanitary science on this side of the Atlantic is the work now being done by the International Joint Commission having control of the pollution of the boundary waters between this country and Canada. This has brought squarely to an issue the proposition of what is a reasonable load as regards pollution that modern water filters may be expected properly to carry. In populated regions surface waters of virgin purity are impossible. This does not mean, however, that pollution can not and should not be controlled within limits that will not prove overburdensome to those whose task it is to build and operate filters and other devices for the purification of public water supplies.

The Rivers Pollution Act of Great Britain, adopted in 1876, was so stringent that it had but comparatively little influence upon the public health, owing to the difficulty and great expense involved in adjusting to it. The Royal Commission on Sewage Disposal of Great Britain decided two years ago, after deliberating for more than a dozen years, that less stringent standards should be set up and that, furthermore, plans for completed works necessary for certain conditions might derive the benefit of " relaxation." By this is meant that local authorities in Great Britain are to-day not obliged, in many cases, to build complete sewage purification works, although plans are to be prepared with that ultimate end in view, and that the construction work to that end must proceed in pursuance of local conditions both as to availability of funds for such work and as to local sanitary needs.

Laboratory methods for measuring the sanitary quality of water date back more than thirty years. They are contemporaneous in point of dates with the formulation and general recognition of the germ theory of disease and the transmission by water carriage of a number of the well-known diseases, particularly those of the intestinal group. Laboratory data do not afford a particularly satisfactory means of measuring the quality of water. They are simply a rough indicator, and the interpretation of the data seems to be positive and satisfactory only when they apply to a very good water or a very bad water. In the middle courses of the range of quality of water, laboratory data are to-day in need of further careful study, both as to methods in use and the interpretation of the results.

Following the Spanish-American war the sanitary world was shocked at the discovery of the extent to which disease was transmitted through the agency of flies and other insects. Those experiences were attained largely in the big army camps where the hygienic environment related more particularly to the conditions prevailing in rural rather than in urban communities. Gradually there has been determined the important fact that public water supplies are not in all cases responsible for the transmission of intestinal diseases to the extent which was hitherto thought to be the case. The recent evidence has been obtained for the most part in southern cities where the fly period is of longer duration than in the northern cities. In the latter, however, the fly period for quite a number of months each year has been a factor involving the public health to a degree much greater than has been recognized by the majority of sanitarians.

Some of the more important recent data will be shown with the aid of lantern slides to illustrate specifically these general remarks as to the need of more precise methods in the laboratory for the measurement of the sanitary quality of public water supplies; and, again, as to means of measurement of the effect of the public water supply upon the general health of the community through recognition of the influence of other aspects of municipal sanitation in bringing about high death-rates from so-called water-borne diseases, and in cases where the public water supplies are in no way at fault.

DETERMINATION OF SPECIFIC PATHOGENIC BACTERIA.

Infectious diseases, such as may be water-borne, require the presence in the water of an appreciable number of the particular pathogenic bacteria producing the disease. It follows very simply, as an academic proposition, that if a correct examination of the water can show that no such disease germs are present, the water is safe for domestic consumption, and is what is generally termed "a wholesome water." Unfortunately, such direct determination can be made only with the greatest of difficulty, and the results of such correct determination have only a doubtful value. A certain number of the bacteria producing water-borne diseases, such as the typhoid bacillus and the cholera spirillum, have been successfully isolated and can occasionally be detected in a polluted water. Broadly speaking, however, it is not at all certain that such bacteria will be detected, even if they are present in a public water supply.

A few investigators, among whom may be particularly mentioned Dr. A. C. Houston, Director of Water Examinations, Metropolitan Water Board, London, have insisted that their methods of determination of these specific organisms are sufficiently accurate and reliable, so that tests made by them showing that these bacteria are not present are conclusive to them that there is no danger of such diseases being caused by the water. Most of the laboratory workers do not concur in this viewpoint. They assert that, while specific bacteria may often be isolated and shown to be present in the water, they are not at all willing to say, on the other hand, that the fact that they are unable to isolate this organism shows conclusively that they are not present. They believe that the methods used are sufficiently uncertain so that typhoid or cholera bacteria may be present and still not be detected.

There is one other important factor which must be considered. We do not know with exact certainty what diseases are disseminated by water. A certain number certainly can be attributed at times to a water supply. Others are uncertain. There may be still others which may be carried by water, but we are not fully aware that they can be so carried. To make satisfactory tests of a water supply, therefore, by the direct method, would require specific tests for each particular type of pathogenic bacteria which we know can be carried by water or which possibly might be carried by water. Quite apart from the accuracy and desirability of results of such methods, the work would probably become so laborious and time-consuming for practical use in ordinary water determinations that the method falls of itself as too unwieldy to be used.

In effect, any such direct methods, ideal as they may be, fail us in service, and we must have recourse to some indirect method which will give us better service. The indirect methods available are, first, the determination of the total number of bacteria present in a given volume of the water, and, second, the determination of the absence or quantitative presence of certain specific bacteria which may be called indicators of the possibility of the presence of disease germs.

SIGNIFICANCE OF TOTAL BACTERIAL COUNT.

The oldest and simplest biological method of gauging the quality of a water supply is by counting the total number of bacteria by means of the colonies formed by growth on some solid nutrient medium. The method formerly used and still in most general practice is to count the total number of colonies produced by incubation on solid gelatine in forty-eight hours at a temperature of 20° Centigrade, and to call this the number of bacteria present in the quantity of water examined (one cubic centimetre). By this standard, German sanitarians about twenty-five years ago fixed on one hundred bacteria per cubic centimetre as the fair dividing line between a good and an unsatisfactory water, under their local conditions as studied. Any water showing less than these one hundred bacteria per cubic centimetre was considered satisfactory, but a bacterial count in excess of this amount showed a water of inferior quality. This standard has been very much used and until fairly recent times has been considered a reasonable and proper standard for some classes of water.

A number of rather obvious objections present themselves to the use of this standard for determining the water quality. The first natural objection is that there may be, and probably is, no definite relationship between the number of bacteria present in the water and the number of pathogenic bacteria which may cause disease. The bacteria in the water originate from any number of points. They come from the soil, the vegetation, and from animals; they grow in the water itself, and many forms multiply very rapidly in the water. A pure water may show very high bacterial results, and a polluted water a relatively small bacterial count.

In considering any new source of water without knowing its special local conditions, it is almost impossible to say from the total bacterial count alone whether the water is good or poor or something intermediate. It even happens that in carefully filtering water the filtered effluent may show as many as, or even more bacteria than, the water applied to the filters. This comes from the fact that certain species of bacteria may grow in the filter itself, particularly in its underdrains, and from this growth of water bacteria, always of a harmless form, the effluent obtains its large bacterial count. And yet this filtered effluent may be entirely free of any pathogenic forms.

Another factor militating against the useful purpose of this total bacterial count test is that the incubation was effected at a temperature of 20° Centigrade, about normal room temperature. Under such conditions the growth of the harmless water bacteria is facilitated, while the growth of the pathogenic bacteria, which naturally thrive at the body temperature, is partially inhibited. It has been attempted to meet this difficulty by specifying a different total bacterial count method of testing. This involves the incubation of the sample at a temperature of 37° Centigrade, using nutrient agar as the medium. The use of the high temperature, approximately that of the body, serves the purpose of encouraging the growth of various bacteria which thrive at the body temperature, and of inhibiting the growth of the ordinary non-pathogenic bacteria. This gives relatively small counts on the plate, but these bacteria, of smaller number, perhaps, may be a fairer measure of the possible presence of contaminating organisms.

Table I of " Comparison of Gelatine and Agar Counts for Various Coli Conditions " exhibits, opposite to each other, the bacterial counts per cubic centimetre obtained by the two methods above cited. It will be seen that the bacteria shown by the 37° agar test are very much lower than those shown by the 20° gelatine test. There is, however, no constant relation between the two. In some cases the agar may show only ten per cent. of the bacteria of the gelatine test. In other cases the count may be twenty-five per cent. or more of those shown by the gelatine test. It is, of course, not to be expected that there should be any constant relation, or even approximately constant relation, between these two tests. In addition, different waters and different conditions of the same water, even different seasons of the year will show a different relation in the count by the two tests.

TABLE I.

COMPARISON OF GELATINE AND AGAR COUNTS PER CUBIC CENTIMETRE FOR VARIOUS COLI CONDITIONS.

Counts shown here are the average for sixteen months

B. coli	Class A water			Class B water			Class C water			Class D water		
	No. of Samples	Gelatine	Agar	No. of Samples	Gelatine	Agar	No. of Samples	Gelatine	Agar	No. of Samples	Gelatine	Agar
Negative in 10 c.c.	...	.....	.....	...	.....	.....	113	920	30	352	44	8
Positive in 10 c.c..	...	.....	.....	...	.....	.....	194	1075	43	75	571	29
Negative in 1 c.c..	14	4741	367	36	9313	845	...	...	...	...	...	...
Positive in 1 c.c...	52	46590	3386	113	42982	5420	71	1655	56	11	715	16
Positive in $\frac{1}{10}$ c.c..	102	45511	11728	166	35641	6443	13	3297	26	...	...	...
Positive in $\frac{1}{25}$ c.c..	94	37762	11177	143	33106	6345	...	...	...	...	...	...
Positive in $\frac{1}{50}$ c.c..	93	35677	9129	101	31727	6821	...	...	...	...	...	...
Positive in $\frac{1}{100}$ c.c..	104	49175	19393	56	38632	11680	...	...	...	...	...	...
Total samples...	459	.....	.....	615	.....	.....	391	...	...	438	...	...

Reference—W. U. C. Baton, Journal Am. W. W. Assn., 1914, Vol. No. 1—p. 19.

An instructive series of investigation has recently been made by Dr. Ernst Quantz, at Göttingen, in Germany, and published in the *Zeitschrift für Hygiene,* 1914, vol. 78, p. 193. Table II shows the results of this investigation made entirely with various well waters. The well waters are divided by the author into three classes: Group I, as shown in the table, consists of wells which are practically impossible for pollution, and may be considered as safely good well waters. Group II are rather doubtful, and at times might possibly be polluted and at other times be pure. Group III are those classed by the author as particularly bad wells, and pretty nearly certain to be polluted.

TABLE II.

BACTERIAL COUNT OF WELL WATERS.

By Dr. Ernst. Quantz—Zeit. f. Hyg.—Vol. 78—Page 193.

Bacterial count per cubic centimetre	Number of examinations			Per cent. of examined wells		
	Group I	Group II	Group III	Group I Good	Group II Doubtful	Group III Bad
0— 10	2	0	0	6	0	0
11— 50	5	10	0	16	9	0
51— 100	3	10	0	9	9	0
101— 200	6	12	1	19	10	3
201— 500	6	22	4	19	19	11
501— 1000	6	18	7	19	15	20
1001— 2000	3	18	7	9	15	20
2001— 5000	1	13	5	3	11	14
5001—10000	0	11	3	0	9	9
10001—20000	0	1	5	0	1	14
Over—20000	0	2	3	0	2	9

In examining these data a very general relationship is shown. Thus, taking 1000 bacteria per cubic centimetre as the limit, we see in Group I that 88 per cent. are under this limit; in Group II, 62 per cent.; and in Group III, 34 per cent. Taking 100 bacteria as the limit, in Group I, 31 per cent. are under this limit; in Group II, 18 per cent.; and in Group III, no per cent. This indicates very fairly that better wells, on an average, have a lower bacterial count than the poorer wells. The author's bacterial count was taken on gelatine at 20° Centigrade.

Individual wells, however, show no such relationship. In some cases good wells show a higher bacterial count than poor wells. Very often the rate of draft on the wells is a bigger factor in the number of bacteria shown than the possibility of pollution. Good wells which have been standing for some time show a very high bacterial count.

The most that can be deduced is that very low counts mean certainly very safe water and very high ones possibly unsafe ones.

As the conclusion of some thirty years of experience, bacterial counts are still taken as showing roughly the variation in the same water. In other words, their chief advantage is found in comparing a water before and after it is filtered. Especially is this true of counts on gelatine at 20° Centigrade.

When taken alone bacterial counts are not considered ordinarily as a reliable indicator of the safety of the water.

SIGNIFICANCE OF B. COLI AS AN INDICATOR OF POLLUTION.

After eliminating as a satisfactory indicator of pollution the total count of bacteria which may originate anywhere at all, the next natural step is to restrict our investigation to those particular bacteria which seem likely to originate in the human body. The normal rule seems to be that only human diseases are transmitted to other human beings, and that bacteria, in order to cause infection, must originate in man. Infectious pollution in water supplies arises almost wholly from discharges from the human intestines, and any bacteria which can be assumed to originate in the human intestines would be a fair measure of such human pollution which potentially might be dangerous or infectious.

Unfortunately, there are no such bacteria which are a positive indicator of human pollution. The nearest thing to it are the coli bacilli. Thus *B. coli* are always found in any discharges from the human intestines. They are also found, however, in the discharges from the intestines of animals, birds, fishes, and on cereals, grains and many other places. They are even found in the air, the dust, and, because of their widespread occurrence, have often been termed "ubiquitous." Because of these conditions it is not a simple matter to say that any water supply which shows the presence of *B. coli* necessarily possesses any specific danger of human pollution or of infection which might at any time have been present. It merely suggests a potential danger in such a water.

This difficulty is made more pronounced by the large number of forms or types in which the *B. coli* appear. The colon bacillus is not a simply definite form of unvarying properties. It represents, rather, a whole class or series of classes of bacteria resembling each other in a certain number of properties and differing in other properties. There is a graded series of bacteria, some of which have in common many qualities, but the extremes of the series have only a small number of things in common. Attempts have been made to divide these coli bacilli into two general classes, one called the typical coli and the other the atypical coli. The typical coli is the one which is most likely to occur in the human intestines, and the atypical coli is that form which is most likely to originate elsewhere.

In 1905 the Committee on Standard Methods of Water Analyses of the American Public Health Association, of which the speaker was a member, drew up a set of standard tests for *B. coli,* designed to distinguish the typical from the atypical form, and to rate only the typical form as *B. coli.*

More modern methods have shown the general tendency to make less difficult and more approximate tests of the occurrence of *B. coli.* They involve the use of the lactose peptone bile "presumptive test" as sufficient to show *B. coli* and to rate coli or coli gas-forming bacteria by this test. There is a good deal to be said for these simpler, speedier methods now used, even if they are not a positive guide for separating the percentage of *B. coli* which comes from the intestines of man, as distinguished from the bacteria reacting similarly in the laboratory and coming from the intestines of other domestic animals, grains, soils, etc.

The percentage of organisms of the coli group, rated as positive by the presumptive test that would be considered typical *B. coli* by confirmatory tests, varies from at least thirty to ninety per cent., according to various workers testing different waters. Quite possibly in some waters the percentage of *B. coli* of typical forms would be much less than this. It is to be understood that even with this small percentage of typical *B. coli* there is no evidence to show what portion, if any, of the *B. coli* originated in the intestines of man.

In Table III the relations of the *B. coli* result by different methods of testing are given. These figures by Professor Gärtner are taken from Dr. Houston's tests of London water. Three methods of testing are given: the first, the so-called presumptive test, is noted from the gas formation; the second column involves a so-called confirmatory test, as applied by Dr. Houston; and in the third column are given the results of so-called typical tests. Comparing the results given by the presumptive test and by the typical test for one cubic centimetre, we see that for the Thames raw water before storage the typical test showed almost as much coli as the presumptive test, or, in figures, about eighty per cent. as much. In the Lambeth Reservoir, after storage, the typical coli are only about fifty per cent. of those shown by the presumptive test. In the Chelsea Reservoir, after storage, the typical coli are shown to be only about forty per cent. as much as the presumptive coli. In the LaValle Reservoir, after storage, the typical coli are less than twenty per cent. of the presumptive coli.

Generally speaking, the raw water shows a higher percentage of typical coli, and storage waters, which are largely purified by long storage, show a smaller percentage of typical coli. This may be because some, even a large part, of the original coli lose their typical properties in age, as is often claimed to be the case. It may be because the typical coli are less long-lived than the atypical coli. It might also be inferred from this table that the typical coli are better indicators of the water quality than the atypical coli.

TABLE III.

RELATION OF B. COLI RESULTS BY DIFFERENT METHODS.

By A. Gärtner—Zeitschrift für Hygiene—1910, vol. lxvii, p. 55.

Source of water	Volume tested c.c.	Per cent. of tests showing positive results		
		Presumptive test	Confirmatory test	Typical test
		Fermentation and gas formation of bile, glucose and peptone solution	Isolation of coli-like microbe, forming gas either in glucose or lactose	Isolation of coli-like microbe, forming indol in peptone water and gas in lactose
Thames, raw water before storage	.0001			
	.001	3.4	3.4	
	.01	27.0	24.7	10.1
	.1	84.3	79.8	48.3
	1.	98.9	97.7	83.1
	10.	100.0	99.9	97.7
	100.	.....	....	99.9
Lambeth Reservoir, after storage	.0001			
	.001			
	.01	1.2	1.2	
	.1	14.9	13.7	7.5
	1.	44.9	39.9	23.7
	10.	82.4	74.9	51.2
	100.	97.4	97.4	83.7
Chelsea Reservoir, after storage	.0001			
	.001			
	.01	1.1	1.1	1.1
	.1	4.5	4.5	3.3
	1.	30.3	22.4	13.4
	10.	65.1	49.3	32.5
	100.	85.3	74.0	57.2
Staines Reservoir, after storage	.0001			
	.001			
	.01			
	.1	3.6	1.2	
	1.	21.7	16.8	9.6
	10.	53.0	44.5	32.5
	100.	84.3	80.6	66.2
Lee River water, before storage	.0001	2.2	1.1	1.1
	.001	11.1	11.2	5.6
	.01	33.6	29.1	16.8
	.1	79.7	75.2	55.0
	1.	99.9	99.9	93.2
	10.	....	....	99.9
	100.			
LaValle Reservoir, after storage	.0001			
	.001			
	.01			
	.1	1.1		
	1.	5.6	2.2	1.1
	10.	16.8	11.1	5.6
	100.	55.0	44.8	32.5

Dr. Houston, in a recent report on the value of storage, points out that storage results in a devitalization of the undesirable bacteria, on account of the water being an unsuitable medium for sustaining their activities. He speaks of this as the "Glagesten" theory in the storage of impure water.

Coli tests should be used most cautiously in forming an opinion as to the quality of an untreated raw water. Such data should be weighed carefully in connection with a sanitary survey in the light of existing conditions as to the opportunity for pollution.

Realizing the inability to record the source of bacteria producing positive results by the coli tests, particularly as to whether or not they originated in the intestines of man, it is desirable to record what is available by way of information as to the relative prevalence in water of *B. coli* and *B. typhoid.* These results, so far as they have been studied, are quite erratic and unsatisfactory. We will make some mention of several comments, but before doing so it is desired to point out some of the irregularities known to the speaker due to changes in methods of determining *B. coli,* as follows:

In 1898 the speaker had charge of the testing station at the Cincinnati water works. The water was drawn from the intake at the old Front Street pumping station, adjoining the Pennsylvania Railroad train shed. Into the Ohio River above this intake there were emptied the contents of thirty-two city sewers, and six miles above the intake the Ohio also received the flow of the Little Miami River, draining a populous watershed. On the basis of the determinative tests made for *B. coli* then in vogue it was found that sixty per cent. of the samples showed the presence of this organism when one cubic centimetre of the water was tested. (See the speaker's report on Water Purification at Cincinnati, 1899, p. 40.)

In 1907 the intake was moved to the present site at California, seven miles above the old intake and one mile above the mouth of the Little Miami River. A marked falling off in the typhoid occurred during the summer of that year, and before the filtration plant was put in service in October of the same year. Since October, 1907, the city of Cincinnati has had one of the very lowest typhoid fever death-rates of any American city. By the present method of making the presumptive tests on the untreated Ohio River water at the upper intake now in use a positive result in one cubic centimetre samples is reported in eighty-five or ninety per cent. of the daily samples tested. No increase in population in Pittsburgh or other cities above can possibly explain the change in analytical data as compared with those obtained in 1898.

At New Orleans, during the operation of the water testing station, Mr. R. S. Weston found in 1901–1902 that out of one hundred tests for *B. coli* he obtained positive results only three times when using from one to three hundred cubic centimetres of water per sample. (See Report on Water Purification Investigation, New Orleans, 1903, p. 47.)

By the presumptive method as now practised positive *B. coli* results are obtained in eighty per cent. or more of the one cubic centimetre samples. The present intake is above the city limits, and there has been no striking increase in the population of the cities of the Mississippi valley sewering into this river of great size. The cities of Baton Rouge and Vicksburg have more extensive sewerage than a dozen years ago, but their effect upon pollution at New Orleans can scarcely be measurable.

INTERNATIONAL JOINT COMMISSION STANDARD.

During the course of this last year an International Joint Commission, consisting of members appointed by the United States and by Canada, have been considering the question of the allowable pollution in international boundary waters. The particular features they were studying were to what extent sewage and other polluting discharges into these boundary waters should be reduced in amount and purified, and to what point these boundary waters might be allowed to be polluted and yet at the same time not occasion, in connection with water purification plants, any menace to public health.

In the course of this investigation this International Joint Commission obtained testimony from a number of sanitary engineers, and formulated a tentative standard of purity for these international boundary waters with respect to the proposition of not overloading water filters.

The problem here was not the one of determining what coli count was permissible for a drinking water. That problem, indeed, could not have readily permitted a general solution in the light of our present knowledge. The conditions of such surface waters as form the international boundary waters are such that safety demands that all of these waters be properly filtered before being used as domestic supplies. The problem, then, relates to the extent of pollution permissible and still not make the waters unsafe after reasonable filtration. Giving proper weight to the effective work that can be expected of modern water filters, it is not necessary to specify a very rigid or exatcing standard for the raw water subjected to filtration. An approximate figure, which will reveal a water not extremely polluted, will be satisfactory. On this basis the speaker and his colleagues before the commission fixed a standard for a yearly average by the presumptive method, reasonably checked by confirmatory tests, of testing coli whereby positive results in 0.1 cubic centimetre samples of water should not occur in more than fifty per cent. of the samples. Averaging this in an arithmetical way, it would mean that there would be not more than about 500 *B. coli* in each 100 cubic centimetres of water. It is, of course, to be understood that such arithmetical averaging is not exactly possible, and the results will not correspond in taking one 100 cubic centimetre sample and in taking one hundred 1 cubic centimetre samples, or one thousand 0.1 cubic centimetre samples.

It is not to be assumed, on this basis, that it is impossible to filter properly a water in which the coli content is in excess of the amount here specified. A water may indeed show a much higher coli content and yet be filtered and sterilized after filtration, so that the resulting effluent will be highly satisfactory for all domestic consumption. Nevertheless, there is a good deal of question, as a matter of broad sanitary policy, whether water which is later to be used for drinking should regularly be allowed to become polluted at the intake to a water supply plant in excess of the amount specified. This standard, indeed, is reasonably liberal, and only unusual conditions will make necessary any very expensive purification of sewage wastes in order to keep water for filtration within the limits of this standard.

Table IV shows *B. coli* content in various water supplies. The results shown here are given on the basis of coli content in one cubic centimetre and in nearly all cases the coli bacilli occur only part of the time in the one cubic centimetre test. In the case of the Lawrence, Mass., water taken from the Merrimac River, and of the Albany, N. Y., water taken from the Hudson River, coli are to be found in 100 per cent. of the tests of the water, and, while the data are not shown in this table, the water roughly approximates to that of the standard tests. Experience has shown, too, that these waters, which are the worst permissible by this standard for filtration purposes, are satisfactorily filtered by the Lawrence and Albany filters, and that the resulting effluent is reasonably satisfactory bacterially for drinking purposes.

TABLE IV.

OCCURRENCE OF B. COLI IN WATER SUPPLIES.

City	Source of supply	Year	Per cent. positive of B. coli in 1 c.c.			
			Raw water	Treated water	Kind of treatment	Presumptive test
Birmingham, Ala.	Five Mile Creek	1910	84.0	8.3	Filtered	Yes
Birmingham, Ala.	Five Mile Creek	1911	78.0	9.7	Filtered	Yes
Birmingham, Ala.	Five Mile Creek	1912	89.0	5.7	Filtered and partly sterilized	Yes
Birmingham, Ala.	Five Mile Creek	1913	78.0	0.0	Filtered and partly sterilized	Yes
Lawrence, Mass.	Merrimac River	1910	100.0	7.8	Filtered	No
Lawrence, Mass.	Merrimac River	1911	100.0	8.4	Filtered	No
Lawrence, Mass.	Merrimac River	1912	100.0	16.9	Filtered	No
New York City	Croton Lake, head	1911	65.0	....	....	Yes
New York City	Croton Lake, dam	1911	21.0	....	....	Yes
New York City	Croton Lake, head	1912	42.0	....	....	Yes
New York City	Croton Lake, dam	1912	35.0	....	....	Yes
New York City	Croton Lake, 135th street	1911	....	29.8	Sterilization	Yes
New York City	Croton Lake	1912	....	10.0	Sterilization	Yes
Philadelphia, Pa.	Torresdale supply	1912	....	4.1	Filtered and partly sterilized	
Little Falls, N. J.	Passaic River	'11–'12	89.0	6.1	Filtered and partly sterilized	Yes
Washington, D. C.	Potomac River	1910	26.9	0.0	Filtered	No
Washington, D. C.	Potomac River	1911	16.9	0.8	Filtered	No
Washington, D. C.	Potomac River	1912	43.5	0.0	Filtered	No
Washington, D. C.	Potomac River	1913	45.5	....	....	No
Harrisburg, Pa.	Susquehanna R.	1910	55.0	0.17	Filtered and sterilized	Yes
Harrisburg, Pa.	Susquehanna R.	1911	77.0	0.61	Filtered and sterilized	Yes
Harrisburg, Pa.	Susquehanna R.	1912	47.0	0.81	Filtered and sterilized	Yes
Clarksburg, W. Va.	Monongahela R.	'11–'12	....	0.3	Filtered and sterilized	Yes
Clarksburg, W. Va.	Monongahela R.	'12–'13	67.0	....	....	Yes
New Orleans, La.	Mississippi River	1913	39.0	3.1	Filtered	Yes
Columbus, Ohio	Scioto River	1913	69.0	0.5	Filtered and sterilized	Yes
Cincinnati, Ohio	Ohio River	1910	91.0	0.8	Filtered and sterilized	Yes
Cincinnati, Ohio	Ohio River	1911	85.0	5.2	Filtered and sterilized	Yes
Cincinnati, Ohio	Ohio River	1912	93.0	3.0	Filtered and sterilized	Yes
Cleveland, Ohio	Lake Erie	1911	11.1	0.0	Sterilized	Yes
Albany, N. Y.	Hudson River	1912	100.0	5.0	Filtered	Yes
Wilmington, Del.	Brandywine Cr.	1911	99.3	....	....	Yes
Wilmington, Del.	Brandywine, Cr.	1912	99.2	11.2	Filtered	Yes
Bangor, Maine	Penobscot River	1913	86.0	0.89	Filtered and sterilized	Yes
London	Thames River	1911	87.9	....	Filtered	No
London	Lee River	1911	86.7	....	Filtered	No
London	Chelsea stored	....	13.4	....	Filtered	No

In view of the importance of the pending investigations into the control of the pollution of the boundary waters between the

United States and Canada, it will not be out of place to include here the guiding principles put before the commission by the sanitary engineers whom they consulted, as follows:

"New York, June 27, 1914.

"To the International Joint Commission.

"Gentlemen: The following statements represent the essence of the opinions given by us before your honorable commission at the conference held in New York on May 26 and 27, 1914:

"1. Speaking generally, water supplies taken from streams and lakes which receive the drainage of agricultural and grazing lands, rural communities, and unsewered towns, are unsafe for use without purification, but are safe for use if purified.

"2. Water supplies taken from streams and lakes into which the sewage of cities and towns is directly discharged are safe for use after purification, provided that the load upon the purifying mechanism is not too great and that a sufficient factor of safety is maintained, and, further, provided that the plant is properly operated.

"3. As, in general, the boundary waters in their natural state are relatively clear and contain but little organic matter, the best index of pollution now available for the purpose of ascertaining whether a water-purification plant is overloaded is the number of *B. coli* per 100 cubic centimetres of water expressed as an annual average and determined from a considerable number of confirmatory tests regularly made throughout the year.

"4. While present information does not permit a definite limit of safe loading of a water-purification plant to be established, it is our judgment that this limit is exceeded if the annual average number of *B. coli* in the water delivered to the plant is higher than about 500 per 100 cubic centimetres, or if in 0.1 cubic centimetre samples of the water *B. coli* is found fifty per cent. of the time. With such a limit the number of *B. coli* would be less than the figure given during a part of the year and would be exceeded during some periods.

"5. In waterways where some pollution is inevitable and where the ratio of the volume of water to the volume of sewage is so large that no local nuisance can result, it is our judgment that the method of sewage disposal by dilution represents a natural resource, and that the utilization of this resource is justifiable for economic reasons, provided that an unreasonable burden or responsibility is not placed upon any water-purification plant and that no menace to the public health is occasioned thereby.

"6. While realizing that in certain cases the discharge of crude sewage into the boundary waters may be without danger, it is our judgment that effective sanitary administration requires the adoption of the general policy that no untreated sewage from cities or towns shall be discharged into the boundary waters.

"7. The nature of the sewage treatment required should vary according to the local conditions, each community being permitted to take advantage of its situation with respect to local conditions and its remoteness from other communities, with the intent that the cost of sewage treatment may be kept reasonably low.

"8. In general, the simplest allowable method of sewage treatment, such as would be suitable for small communities remote from other communities, should be the removal of the larger suspended solids by screening through a one-fourth-inch mesh or by sedimentation.

"9. In general, no more elaborate method of sewage treatment should be required than the removal of the suspended solids by fine screening or by sedimentation, or both, followed by chemical disinfection or sterilization of the clarified sewage. Except in the case of some of the smaller streams on the boundary, it is our judgment that such oxidizing processes as intermittent sand filtration, and treatment by sprinkling filters, contact beds, and the like, are unnecessary, inasmuch as ample dilution in the lakes and large streams will provide sufficient oxygen for the ultimate destruction of the organic matter.

"10. Disinfection or sterilization of the sewage of a community should be required wherever there is danger of the boundary waters being so polluted that the load on any water-purification plant becomes greater than the limit above mentioned.

"11. It is our opinion that, in general, protection of public water supplies is more economically secured by water purification at the intake than by sewage purification at the sewer outlet, but that under some conditions both water purification and sewage treatment may be necessary.

"12. The bacteriological tests which have been made in large numbers under the direction of the International Joint Commission indicate that in most places the pollution of the boundary waters is such as to be a general menace to the public health should the water be used without purification as sources of public water supply or should they be used for drinking purposes by persons travelling in boats.

"13. It is our judgment that the drinking water used on vessels traversing boundary waters should not be taken indiscriminately from the waters traversed, unless subjected to adequate purification, but should be obtained preferably from safe sources of supply at the terminals.

"14. While recognizing that the direct discharge of fecal matter from boats into the boundary waters may often be without danger, yet in the interest of effective sanitary administration it is our judgment that the indiscriminate discharge of unsterilized fecal matter from vessels into the boundary waters should not be permitted.

"Yours respectfully,

"GEORGE W. FULLER,
EARLE B. PHELPS,
GEORGE C. WHIPPLE,
W. S. LEA,
T. J. LAFRENIERE."

Mr. F. A. Dallyn, who was one of the six consulting engineers to advise the commission, presented a minority report, in which he eliminated Paragraphs 5, 7, and 11, and made a few slight changes in some of the other paragraphs.

BACTERIOLOGICAL STANDARD FOR DRINKING WATER ADOPTED BY THE TREASURY DEPARTMENT FOR WATER SUPPLIED TO THE PUBLIC BY COMMON CARRIERS IN INTERSTATE COMMERCE.

On October 21, 1914, the Treasury Department adopted the standard for interstate carriers for water supplies for public drinking purposes in accordance with the recommendations by a commission appointed by the Secretary of the Treasury, January 22, 1913. This commission of fifteen sanitarians recommended a standard published in the United States Public Health Reports, vol. 29, No. 45, p. 2960, dated November 6, 1914, as follows:

> "1. The total number of bacteria developing on standard agar plates incubated twenty-four hours at 37° Centigrade shall not exceed 100 per cubic centimetre: *Provided* that the estimate shall be made from not less than two plates, showing such numbers and distribution of colonies as to indicate that the estimate is reliable and accurate.
>
> "2. Not more than one out of five 10 cubic centimetre portions of any sample examined shall show the presence of organisms of the bacillus coli group when tested as follows:
>
> "(*a*) Five 10 cubic centimetre portions of each sample tested shall be planted, each in a fermentation tube containing not less than 30 cubic centimetres of lactose peptone broth. These shall be incubated forty-eight hours at 37° Centigrade and observed to note their formation.
>
> "(*b*) From each tube showing that more than five per cent. of the coli are in the fermentation tube, plates shall be made after forty-eight hours' incubation upon liquid lactose litmus agar or endo media.
>
> "(*c*) When plate colonies resembling *B. coli* develop upon either of these plate media within twenty-four hours, a well-isolated characteristic colony shall

be fished and transplanted into a lactose broth fermentation tube which shall be incubated at 37° Centigrade for forty-eight hours.

"Examining this above recommended standard, it will be noted that, roughly proportioning, twenty per cent. of the 10 cubic centimetre samples will be permitted to give positive indications of *B. coli*. These tests, however, are not to secure presumptive tests of the lactose peptone bile gas formation method; they are something nearer to the typical coli test. Accordingly the number of samples showing *B. coli* by presumptive tests may well run to forty per cent. of the 10 cubic centimetre samples. Comparing this forty per cent. standard, we note that the New York drinking water, as supplied in the 135th Street gate-house, showed a yearly average, in 1912, of forty-four per cent. positive results in 10 cubic centimetre samples, and in 1911 an average of seventy-six per cent. positive results.

"Assuming that water with forty per cent. positive results corresponds with the recommendations of the committee, the efficiency of the filtration and sterilization system, when compared with the permissible limits in raw water for filtration purposes as recommended by the International Joint Commission's sanitary experts, ought to correspond roughly to ninety-nine per cent."

The Treasury Commission state further as quoted herein:

"The bacteria developing on standard gelatine at 20° Centigrade include a relatively large proportion of harmless bacteria, which are normally inhabitants of falls and natural waters, free from dangerous pollution. The number of bacteria as estimated by the standard gelatine count serves in a general way as an index of the cleanliness of the sample; but to properly interpret the result of such a count it is necessary to have knowledge of the source of the sample examined and the nature of the pollution to which it has been exposed and the opportunity afforded for multiplication of the harmless varieties of bacteria present; on account of rapid multiplication of harmless varieties of bacteria which may take place when water is stored in small containers at moderate temperatures, and the impossibility of making approximately correct allowance for such multiplication, it is believed that the attempt to establish a limit to bacteria developing on gelatine is not practicable for the purposes of the control of supplies of common carriers.

"The bacteria developing on standard agar at 37° Centigrade in twenty-four hours are also chiefly varieties which are entirely harmless. The agar count, however, as compared with the gelatine count, represents a larger proportion of bacteria which find their normal habitat in the animal body and are present in sewage and other discharges from the animal body. Generally speaking, an accepted agar count is sufficient to cause at least a suspicion that the water is polluted with discharges from animal bodies, and is therefore unsafe for use as a drinking water. Multiplication of the harmless varieties present may, however, take place at ordinary temperatures in water stored in tanks, coolers, bottles, and other containers, thus greatly increasing the agar count without, of course, increasing the actual dangerous pollution of the water. This introduces a large source of error into the attempt to interpret the significance of agar count of samples of water stored for varying lengths of time under conditions more or less favorable to bacteria multiplication. It is largely for this reason that it has been considered necessary to allow varying limits to the agar count of the water supplies of common carriers, and to attach to the result of this method of examination a significance much less than ordinarily attaches to the agar count in examining samples of water especially removed from known sources.

"Bacteria of the bacillus coli group are normally inhabitants of the intestinal tract of warm-blooded animals, and it is believed that under ordinary conditions they do not multiply in nature outside of the animal

> body; that in drinking water supplies they tend, on the contrary, to die out rather rapidly. The presence of such bacteria in the water may accordingly be considered valid evidence that the water has been polluted with the intestinal discharges of some of the higher animals, and the numbers present should be considered a fair index of the extent of such pollution. Since practically all of the diseases which are known to be commonly transmitted through water supplies are due to germs which are discharged from the intestines of infected persons, pollution with intestinal discharges is not only the most offensive but by far the most dangerous kind of pollution to which water supplies are exposed.
>
> " Compliance with the requirements herein recommended will insure a quality of water supply equal to that of municipal supplies which have been demonstrated by experience to be entirely safe and satisfactory, and will at the same time impose no great burden upon common carriers, since it is entirely practicable with moderate direct expense and pains to purify water to the degree required."

A comment which may be made upon this report of the Treasury Commission is that, while the standard they set is proper under the conditions for which they place it,—that is, a single standard for the testing of large varieties of water from different unknown sources,—and will give practically a safe water under any such conditions, a somewhat more liberal standard might well be applied in the case of a municipal water supply where the source of the water is known and its possibilities of being subjected to pollution can be investigated on the ground. Under these latter conditions a higher *B. coli* content may be well in accord with a good and wholesome water.

INTERFERENCE WITH THE PRESUMPTIVE COLI TEST BY OTHER SPECIES OF BACTERIA.

For some time it has been known by bacteriologists that *B. Welchii, B. enteritidis,* and some other streptococci interfere with the so-called presumptive bile test for *B. coli*. The details of the discussion concerning these complications are beyond the scope, bacteriologically, of this address. It is sufficient to state that they are serious and that they require far more consideration than was thought to be the case a few years ago.

It appears that *B. Welchii* and some other forms of bacteria grow anaërobically and ferment nutrient carbohydrate solutions, although they may not grow on aërobic plates.

Columbus Experiences.—One of the most striking experiences which have come to the attention of the speaker was noted a week or two ago in connection with the operating of the filtering and softening plant of the water works of Columbus, Ohio. This plant, skilfully operated under the charge of Mr. Charles P. Hoover, deals with very hard water during the autumn months. Lime and soda are added to soften it, and as a result large quantities of gelatinous, flocculent precipitate of basic carbonate of magnesia are formed. This brings about a very high degree of bacterial removal as an incident to the softening process and prior to filtration. In a single week there were five days on which numerous samples of the softened and filtered water showed in no instance any bacteria either on gelatine plates or agar plates cultivated either for forty-eight hours at 20° or twenty-four hours at 37°. By ordinary procedures the filtered water was sterile. Yet in fully half the samples of this sterile water positive results were found by the presumptive test for *B. coli* when 10 cubic centimetres of water were employed.

During the past autumn similar results, but less strikingly frequent, have been noted in connection with the operation of the softening and filtration plant of the water works at Grand Rapids, Mich., and the filtration plant at Evanston, Ill.

At Columbus the bacterial flora of the Scioto River water have been studied with unusual care by Messrs. Copeland and Hoover, who in the *Journal of Infectious Diseases,* vol. 8, p. 241, 1911, contributed an important paper on "The Interpretation of Tests for B. Coli Communis."

The concluding paragraph of this paper is of much practical importance to water works officials having the responsibility of caring for the quality of municipal water supplies:

> "*B. coli* is found in sewage, and therefore its presence is significant; but, as newspaper reporters and other persons are inclined to magnify conditions, the

> officers in charge of purification works should be careful to identify suspicious organisms as true *B. coli* before throwing suspicion upon their plants and prejudicing the minds of the people. With this end in view, the procedure outlined in the diagnostic table gives a ready method of proving whether waters do or do not contain *B. coli communis,* and the necessity of such procedure is illustrated by the variety of organisms which less thorough tests would include erroneously in the group."

GOVERNMENT EXAMINATION OF DRINKING WATER ON RAILROAD TRAINS.

In Bulletin No. 100 of the Hygienic Laboratory of the United States Public Health Service, Treasury Department, there is an important paper on this subject by Richard H. Creel. This entire paper, appearing in November, 1914, is worthy of most careful study, and particularly with reference to the light it throws upon the "bile presumptive test for colon bacillus." It deals particularly with anaërobic bacilli, found in the water of train coolers, which complicate the ordinary so-called coli tests. It speaks of several groups of bacteria which are obligate anaërobes. Concerning the reliability of the presumptive tests, we quote as follows:

> *"Bile Presumptive Test for B. Coli."*
>
> "The difference between the actual *B. coli* percentage in the 1000 samples examined and that which would have resulted had the lactose bile presumptive test been used is as follows, the comparison applying only to tubes containing water in 10 cubic centimetre amounts:
>
> | Number of Samples | Gas | B. Coli | Anaërobe | Actual B. Coli Per cent. | Bile Presumptive B. Coli Per cent. |
> |---|---|---|---|---|---|
> | 1,000 | 421 | 91 | 330 | 9.1 | 22.1 |
>
> The margin of error is greater in relatively pure water than in water of moderate pollution.
>
> "Estimated according to the different trains, the comparison is as follows:

	Actual *B. Coli* Per cent. Confirmed.	Percentage of *B. Coli* According to Lactose Bile Presumptive Test.	Number of Samples.
Train 301, Pennsylvania Railroad (sleeping cars)	4.7	25	151
Train 84, Seaboard	6.3	17.5	59
Train 305, Pennsylvania Railroad (sleeping cars)	3.4	20	125
Train 305, Pennsylvania Railroad (coaches)	5.3	16	57
Train 82, Atlantic Coast Line (coaches)	32.	54	50
Train 82, Atlantic Coast Line(sleeping cars)	14.	17	144

"It will be noted that there is a wide divergence between the real and the presumptive percentage when the water is fairly pure, but that in moderately polluted water, as that from Train 82, there is less discrepancy. In the latter class of water the approximation of the two figures seems to be due to the inhibiting effect of lactose bile on the *B. coli*. From the foregoing results the 'presumptive test' for *B. coli* does not seem applicable for analyzing water of moderate pollution, as its employment would often result in condemning a water of acceptable standard of purity."

RECENT ENGLISH COMMITTEE REPORT ON THE STANDARDIZATION OF BACTERIOSCOPIC METHODS OF WATER EXAMINATION.

In the autumn of 1914 a committee of thirteen leading bacteriologists and sanitarians appointed in March, 1914, by the Royal Institute of Public Health of Great Britain, reported on this subject. It is not practicable to repeat all of the technical details, but it is of interest to note what they say with regard to standards, especially in connection with the caution which they urge against wording reports to give unnecessary alarm, as follows:

"*Standards.*

"The committee do not think it is practicable to lay down any fixed standards to govern all cases. Speaking generally, the committee consider that too

> much stress should not be laid on the number of microbes present in a water, unless the *B. coli* tests yield confirmatory results.
>
> " A good water should not contain any *B. coli* in 100 cubic centimetres, but a water containing *B. coli* in 100 cubic centimetres should not necessarily be objected to without the examination of further samples.
>
> " Experience has shown that even initially impure waters may be purified at a reasonable cost, so as to yield no *B. coli* in 100 cubic centimetres in the majority (about seventy-five per cent.) of samples examined.
>
> " It is much more difficult to suggest a standard by which a water should be condemned. All that the committee feel justified in stating is that the further a water departs from the above standard of purity (no 'lactose + indol + ' *B. coli* in 100 cubic centimetres) the greater is the suspicion attaching to it, unless the local conditions and circumstances are such as to exclude undesirable pollution."

NEED OF FURTHER CONSIDERATION OF BACTERIOLOGICAL METHODS.

There is a feeling among some water works men that the recent standard proposed by the Federal Government for the quality of drinking water supplied to the public by common carriers in interstate commerce will cause annoyance and perhaps some serious trouble to municipal water supplies that are generally believed to be of safe and satisfactory quality. At any rate, the Treasury Department report above quoted from at length will unquestionably stir up a helpful agitation as to the reliability of bacteriological methods of analysis and accentuate the need of more care being exercised in the future than in the past.

No doubt there are places where the bile presumptive test for *B. coli* is markedly helpful, and its use in many places will no doubt be urged by the extremists who wish to be ultra-conservative in insisting upon the highest purity for public drinking water supplies. Nevertheless, the evidence, on the whole, points to the ease with which gross injustice against some important water supplies might be brought about.

It seems important to have the standard methods of bacterial water analysis thoroughly reviewed and brought to date. And it is understood that the American Public Health Association, through its Laboratory Section, appointed a new committee to deal with this subject (Jacksonville, Fla., Convention, December, 1914).

WATER SUPPLIES AND TYPHOID FEVER.

The general relation between deaths from typhoid fever in a community and the quality of the water supplied to it has long since been established. It is well known that ordinarily in towns where water supplies are relatively good, typhoid fever cases and deaths are relatively low, and for towns where a water supply is assumed to be impure the converse is true. The relation is, of course, not at all an exact one.

Table V gives the annual typhoid fever death-rate for various American cities, noted in deaths for 100,000 population, from the years 1880 to 1914. Notes are made of various improvements in the water supplies at certain times, and the change of death-rate accompanying this gives some information as to the resulting effect on the population.

In the first column are data for the city of Chicago, when at the beginning of the year 1894 or the end of the year 1893 a new intake was put into service. This is marked with a little note "4." The effect on the typhoid fever death-rate was very marked, indeed, as this rate dropped from 54 in 1893 to 38 in 1894, and it is probably safe to say that at least some part of this reduction is the result of the improvement of the water. In 1900 the new Chicago Drainage Canal was put into service. The effect of this introduction was, however, less marked.

The cities of Milwaukee and Detroit show a relatively uniform rate during the last twenty years, and no material change in the water supply system has been made in those cities during that time.

The city of Cleveland shows marked improvement, due to the introduction of a new intake in 1905, and again in 1912, when the water was sterilized for the first time.

In the column showing the deaths in the city of Buffalo there are no very significant figures. A new intake was introduced in 1911, but the time since then is rather too short to suggest any positive inferences.

For the city of Toronto the filtration plant was started in 1911.

TABLE V.

ANNUAL TYPHOID FEVER DEATH-RATES FOR VARIOUS AMERICAN CITIES IN DEATHS PER 100,000 POPULATION

Year	Chicago	Milwaukee	Detroit	Cleveland	Buffalo	Toronto	Boston	New York	Manhattan and the Bronx	Philadelphia	Baltimore	Washington	Cincinnati	Pittsburgh	San Francisco	St. Louis	New Orleans
1880	34	37	..	44	..	44	42	25	..	58	59	54	70	135	34	40	24
1881	105	47	..	99	67	66	56	38	..	74	58	46	71	151	37	53	30
1882	82	32	..	68	69	71	57	32	..	73	47	66	55	158	61	45	33
1883	62	25	..	65	34	81	52	32	..	64	35	62	51	107	64	41	23
1884	56	31	..	60	42	63	56	29	..	71	42	76	56	70	58	42	25
1885	75	28	..	34	23	59	40	27	..	64	42	65	42	76	44	31	17
1886	69	30	39	56	28	46	34	26	..	64	39	71	54	68	49	30	13
1887	50	31	65	52	34	61	44	26	..	63	41	78	142	128	23	28	15
1888	47	42	46	47	29	52	40	23	..	77	42	87	70	87	33	31	19
1889	48	28	31	74	30	46	43	24	..	71	47	94	49	95	55	33	17
1890	92	41	19	69	40	93	35	22	..	64	59	112	69	132	44	31	21
1891	174	33	34	50	51	100	34	23	..	64	35	82	62	101	42	29	24
1892	124	30	94	59	34	47	29	22	..	40	44	89	40	100	32	93	20
1893	54[4]	35	42	52	37	45	31	21	..	41	49	86	44	111	32	44	15
1894	38	25	28	29	59	26	29	17	..	33	47	91	55	56	37	34	29
1895	38	26	24	35	26	27	33	17	..	40	36	86	39	78	34	21	44
1896	53	18	23	43	20	27	31	16	..	34	38	58	52	62	26	20	33
1897	29	12	15	23	20	18	33	16	..	33	37	48	32	64	19	23	52
1898	41	17	22	34	27	16	34	21	..	52	36	71	33	73	41	17	66
1899	27	17	13	32	24	20	30	16	..	75	29	73	37	111	22	23	55
1900	20[3]	17	27	54	26	20	26	21	..	35	35	78	39	144	13	29	40
1901	29	22	21	36	27	17	25	20	..	34	27	60	55	125	22	34	48
1902	45	15	24	33	33	13	24	21	..	44	42	78	62	134	27	37	45
1903	32	17	20	114	35	16	20	17	..	69	36	48	42	134	..	47	39
1904	20	14	20	48	23	23	23	17	..	53	37	47	79	142	27	36	36
1905	17	23	21	15[4]	23	16	20	16	..	48	36	48	40	99	24	20[5]	32
1906	19	31	24	20	23	26	20	15	..	72	35	50[1]	70	130	..	17	30
1907	18	26	35	19	28	22	10	17	..	59	41	35	45	125	..	15	55
1908	16	17	22	13	20	20	25	12	11	35	33	37	18[1]	45	..	14	33
1909	13	23	23	13	23	23	14	12	12	21[1&2]	25	33	13	23[1]	..	16	29[1]
1910	14	45	20	19	20	41	12	12	11	17	42	23	6	28[2]	..	13	32
1911	11	19	17	15	25[4]	20[1]	9	11	10	14	27	21	11	26	..	11	31
1912	8	25	18	6[2]	11	12	8	10	7	13	24	22	7	13	14	14	14
1913	11	11	29	13	15	10	8	7	6	16	26	..	6	19	..	16	17
1914	7	8	12	8	16	7	9	6	5	7	22	..	6	..	..	11	20

Note: New York includes Borough of Manhattan only through 1898—since 1898 Greater New York

[1] Filtration effective for city.
[2] Sterilization of water supply begun.
[3] Drainage Canal in service.
[4] New intake
[5] Coagulation introduced.

The city of Boston shows a rather satisfactory and gradual reduction of typhoid during the last twenty years, without any very marked changes in the entire water supply. In 1898 the Wachusetts water supply was introduced, showing some reduction in typhoid fever as a result.

For the city of New York the reduction has also been rather gradual. The only notable point is for the year 1893–1894, when particular measures were taken to reduce the pollution on the Croton watershed by removing sewage discharges from houses within a 300-foot line of the reservoirs and principal feeders.

The situation in the city of Philadelphia you are no doubt all familiar with. The filters, which have improved the typhoid situation to such a marked extent in this city, were introduced gradually, beginning about the year 1903. The West Philadelphia Belmont filters were added in 1906; the Torresdale plant was started in part service in 1907. By the year 1909 most of the city was supplied with filtered water, and where no filtered water was afforded the balance was sterilized. The final addition of the Queen Lane plant, in 1911, gave filtered water to the whole city. The reduction in typhoid fever as a result of this gradual introduction of filtered water into the city is very noticeable. In 1914 Chief Davis states that the annual death-rate from typhoid fever was 7.48 per 100,000.

The city of Baltimore shows no very marked reduction, but, with the addition of the new water filters which will be in operation before very long, we can expect to find quite a lessening of the typhoid rate.

The city of Washington showed rather disappointing results in the matter of filtration, particularly in the earlier years. Although the reduction of typhoid at first was by no means as marked as was expected in advance, yet the later figures have been much more satisfactory.

The figures for the city of Cincinnati following filtration are quite remarkable. The reduction was very sharp, and the typhoid rate for the last five or six years has been only about one-third, or even less, of what it was during the preceding years.

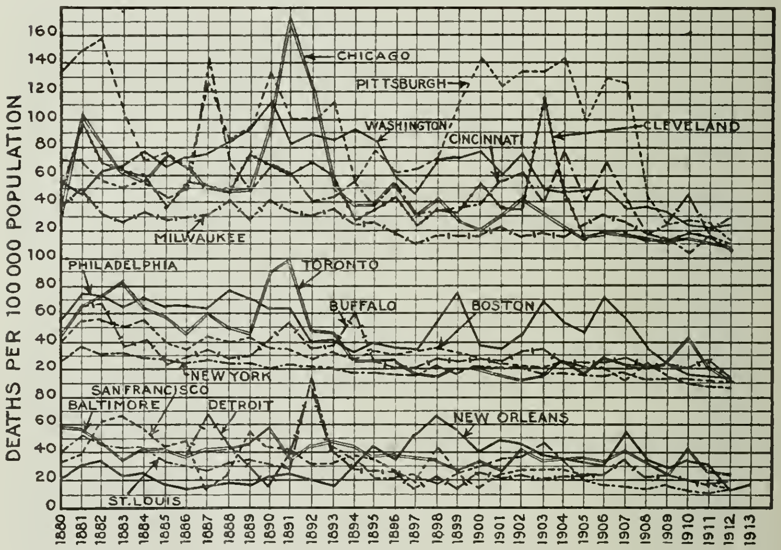
The city of Pittsburgh shows similarly satisfactory results. The introduction of filtered water in 1909 effected a very marked reduction of typhoid fever, even if some unfiltered water was still supplied.

In the column showing the results in the city of St. Louis a moderately satisfactory reduction has been effected by the addition in the year 1904 of the coagulating plant to the St. Louis water works system, aided by prolonged sedimentation arrangements and later by sterilization. Filters are now being built.

The New Orleans results show some satisfactory reduction recently, but a good deal less than has been found in other cities.

Fig. 1 shows the results of the foregoing table represented graphically. The scale of the drawing does not indicate very clearly what the effect of changes in the water supply has been. A few of these curves stand out very clearly. In the upper line the reduction in the typhoid rate of the city of Pittsburgh is remarkable over all the others. The line showing the city of Cincinnati gives a very marked reduction. In the second line the effect on the city of Philadelphia is very noticeable.

FIG. 1.

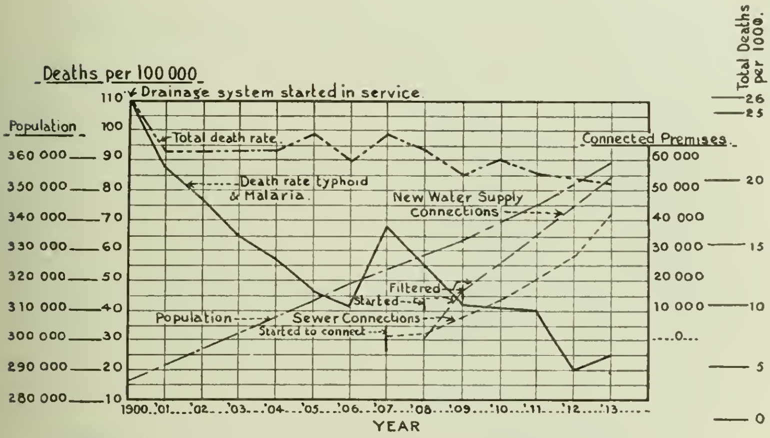


ANNUAL TYPHOID FEVER DEATH RATES FOR VARIOUS AMERICAN CITIES

Fig. 2 shows some detailed results from the city of New Orleans. Here are plotted the deaths for each year per 100,000 population from typhoid and malaria combined. These figures are, of course, materially higher than the typhoid deaths alone, but it seems not unlikely that they represent more accurately the improvement effected by the introduction of the sanitary sewer system and the new filtered water supply. A part of the surface drainage system was put in service in 1900. Sewer connections to the sanitary sewer system were started in the year 1907 and have gradually increased. The filtered water supply was started by the city in the year 1909.

From the start of the surface drainage system a very satisfactory reduction in typhoid fever and malaria is to be found. During 1913 the deaths from typhoid were seventeen per 100,000, and for malaria six, making a total of twenty-three per 100,000 population, a figure not at all unsatisfactory, when it is considered that there is still a part of the city not supplied with either sewer connections or filtered water, and that local conditions of temperature, flies, and other items, exercise a material effect on the typhoid and malarial fever death-rate. The removal of storm water and sewage which formerly pooled on the surface of the ground has been the controlling item.

FIG. 2



TYPHOID & MALARIA DEATH RATE AND TOTAL DEATH RATE & SEWERAGE & WATER SUPPLY & DRAINAGE. NEW ORLEANS-LA.

HAZEN'S THEOREM.

In the year 1893 it was stated by Dr. J. J. Reinicke, of Hamburg, Germany, and Mr. Hiram F. Mills, C.E., of Lawrence, Mass., that the purification of the polluted public water supplies of Lawrence and Hamburg was producing a general decline in the death-rate of each of these cities. In 1904 Mr. Allen Hazen, in his paper on "The Purification of Water for Domestic Use" before the International Engineering Congress, formulated a deduction from certain data similar to this, as follows:

> "This computation indicates that where one death from typhoid fever has been avoided by the use of better water, a certain number of deaths, probably two or three, from other causes have been avoided. This seems the clear and logical conclusion from the statistics."

Mr. Hazen's tabulation from which he deduces this statement is the following:

Reduction in total death-rate in five cities with the introduction of a pure water supply	440 deaths per 100,000 population
Normal reduction, due to generally improved sanitary conditions, computed from average of cities similarly situated, but with no radical change in water supply ...	137 deaths per 100,000 population
The difference being decrease in death-rate attributable to change in water supply	303 deaths per 100,000 population
Of this the reduction in deaths from typhoid fever was	71 deaths per 100,000 population
Leaving deaths from other causes attributable to change in water supply ...	232 deaths per 100,000 population

This question was further considered in detail by Professor W. T. Sedgwick and Mr. J. Scott McNutt, in the *Journal of Infectious Diseases,* vol. 7, p. 489, in their paper entitled "On the Mills-Reinicke Phenomenon and Hazen's Theorem Concerning the Decrease in Mortality from Diseases other than Typhoid Fever Following the Purification of Public Water Supplies."

The authors of this paper came to a conclusion as follows:

> "Mr. Hazen's quantitative expression for the Mills-Reinicke phenomenon, when applied to the cities which we have studied (with the exception of Watertown), appears sound and conservative. It seems

> likely, however, that it will be impossible in the future to confine the relation even within the broad numerical limits suggested by Mr. Hazen."

This general subject is dealt with by the speaker in his book on Sewage Disposal, pp. 107–16. It appears that the Hazen theorem seems to apply chiefly in those cities having formerly a grossly-polluted water supply. Where improved supplies have been installed for cities which previously had only a moderately-polluted supply the improvement in general death-rate has been far less marked than at Lawrence, Albany, Hamburg, etc.

The danger of too definite conclusions as to the exact effect of the filtered water and its relative effects on the typhoid death-rate is quite great. Still greater may be the danger of any definite conclusion as to the effect of water supply on the total or general death-rate.

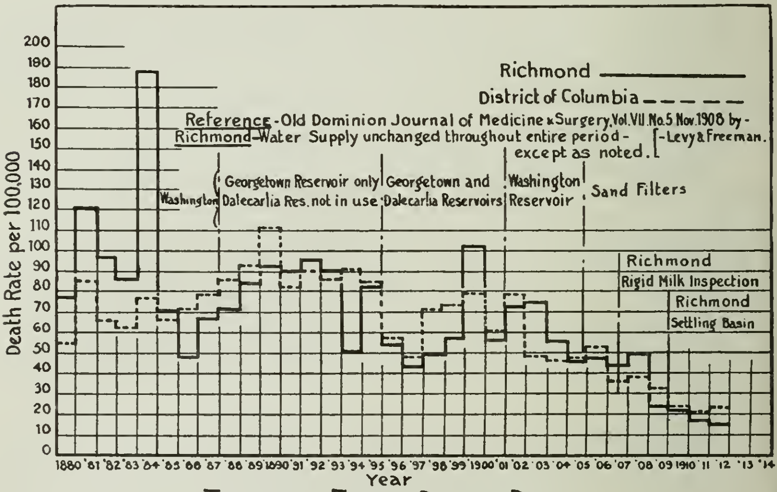
The fact that it is impossible to attribute to improved water supply all the reduction of typhoid rate, following such introduction of improved water supplies, is shown on Fig. 3. These data are taken from a paper written by Drs. Levy and Freeman in the *Old Dominion Journal of Medicine and Surgery,* vol. 7, No. 5, November, 1908, and show two lines of the typhoid fever death-rate, including malaria, for the cities of Richmond, Va., and the District of Columbia, including the city of Washington.

The heavy line on this diagram gives the result for the city of Richmond. During the period under consideration, from 1880 to 1909, there was practically no change made in the city of Richmond water supply. The Richmond water is not filtered, but there is no reason to believe that there was any great amount of pollution or disease resulting from this unfiltered water. In the year 1909 an additional settling basin was provided for the Richmond water supply, as noted on the digaram.

The Washington water supply, as shown in the diagram, was considerably improved during this period. At the end of 1887 we note that only the Georgetown Reservoir was in use. In 1895 the Dalecarlia Reservoir was added. In 1901 the Washington Reservoir was added. The filters were put into service in 1905.

Broadly speaking, there seems to be no particular difference between the typhoid fever rate shown in the Washington and the Richmond cases. There are some specific cases where very high figures are shown in Richmond, notably in 1880 and 1881, when there seems to have been an epidemic. In 1884 there was a very heavy epidemic indeed. In the year 1900 the Richmond curve shows likewise an epidemic. Apart from these special dates, the Richmond curve practically follows the Washington curve, and the typhoid fever rate is almost the same throughout. It is particularly noticeable in the later years since the Washington filters were added. Since this time a marked improvement in typhoid fever has been found at Washington, and a similar improvement can be found in the city of Richmond. The improvement in the city of Richmond was largely caused by sanitary measures, particularly that of instituting a rigid milk inspection. The date of the starting of this rigid milk inspection is noted on the diagram.

FIG. 3.



TYPHOID FEVER DEATH RATE
(Including Typho-Malaria)
RICHMOND & DISTRICT OF COLUMBIA
1880–1914

It is not an unfair inference to say that a large part of the reduction in typhoid fever in Washington was owing, not to this improved water filtration, but to other sanitary measures which were introduced at about the same time.

There is one important factor, however, which differentiates the effect of an unfiltered water supply from the effects of a filtered water supply. An unfiltered water supply which may be subjected to occasional gross pollution may produce at intervals a very serious epidemic. Such an epidemic may easily run the typhoid fever rate to several times the normal for a period of a year. Such an epidemic can hardly occur with a properly-filtered water supply. In this lies the particular value of filtration. Typhoid fever as a whole may or may not be reduced in any particular locality by the introduction of filters. In some cases there has been a marked reduction of typhoid attributable only to the filtration and to nothing else. In other cases, as at Washington, such reduction as has been noted is probably not to be attributed chiefly to the filters, but to other sanitary measures.

It is not to be asserted as a general rule that filters must eliminate the typhoid fever and other similar sicknesses in any town. It can, however, be asserted without qualification that such filters will practically eliminate any chance of a typhoid epidemic, and thus make the water supply safe. A surface water supply without filtration or sterilization or prolonged storage cannot ordinarily and uniformly be considered safe. Even under the best of conditions and under the most favorable inspection the water of flowing streams may at times be subjected to pollution which may cause typhoid epidemic.

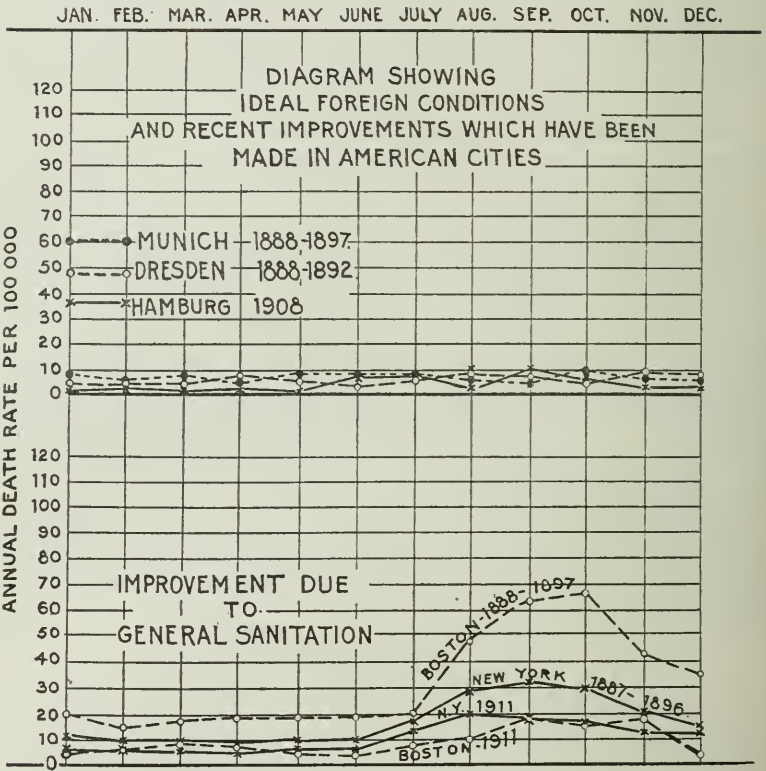
Dr. A. C. Houston, of London, in his recently-issued book "Studies in Water Supply," considers the question of the relation of water and disease, and from this book we quote several sections, as follows:

> "There can be no question that in a number of American cities improvement of water supply has antedated the decrease of mortality, but in our present state of incomplete knowledge to conclude from this circumstance a direct causative connection between these two is perhaps hardly warrantable in all cases.
>
> "The fact that there has likewise occurred a decline in the incidence of tuberculosis, pneumonia, and respiratory diseases generally, none of which can reasonably be regarded as at all likely to be water-borne, throws some doubt on the hypothesis that an improved

water supply necessarily tends to produce any marked and continuously operating decrease of mortality from general and particular diseases.

"The author is, of course, not suggesting, in the face of conclusive evidence to the contrary, that serious typhoid epidemics have not resulted from the consumption of specifically polluted water, or that any relaxation in the processes of water purification is permissible; he does venture to express the opinion that the evidence brought forward in favor of the direct causative relationship between the quality of water supplies and the degree of incidence of endemic typhoid fever is not always wholly convincing.

FIG. 4.

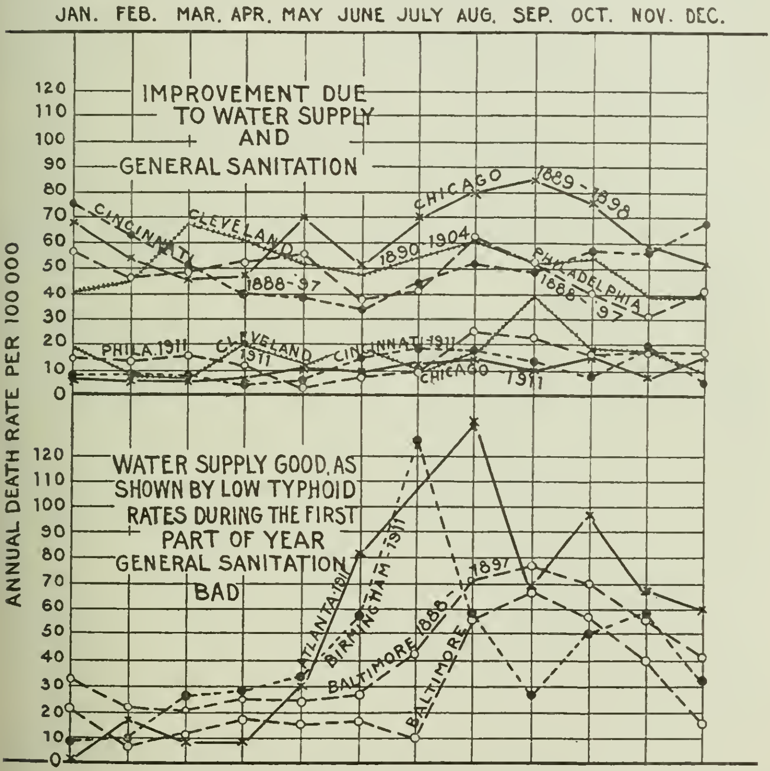


YEARLY TYPHOID FEVER DEATH RATES.

"It is impossible, of course, to accept any theory which associates diminution of the typhoid fever rate as attributable to improved water supply, but seems to ignore increased incidence of the disease as of water significance."

Fig. 4, modelled after Jackson's data in his Cleveland report of 1913, shows some yearly typhoid fever death-rates under various conditions for a number of cities. The first section, in the upper left-hand corner, gives a diagram showing certain foreign cities (Munich, Dresden, and Hamburg) with actual annual typhoid fever death-rates per 100,000, running in all cases below ten and averaging about five. The conditions represented by these figures are practically ideal. It is well

FIG. 4.—(*Concl.*)



YEARLY TYPHOID FEVER DEATH RATES

worthy of note in these lines showing death-rate for various months during the year that incidence of typhoid fever is practically constant during the whole year.

The second section of the diagram, in the lower left-hand corner, shows improvements effected in two cities by general sanitation. The heavy line represents the city of New York. The upper line shows the New York typhoid for the years 1887–1896; the lower solid line, New York conditions for the year 1911. There has, during this time, been very little, if any, change in the water supply; in any case, not a very serious change. The improvements in typhoid fever death-rate must be looked for in other directions.

The two Boston curves are shown by the dash line: the upper one, Boston from 1888 to 1897; the lower one, Boston in 1911. The improvement here is very much more marked, and is also to be explained largely by improvements in general sanitary conditions, although partly by the Wachusetts water supply, introduced in 1898.

The next part of the diagram, the upper right-hand corner, shows combined improvements effected through change in water supply and general sanitation. It is not possible very exactly to divide the effect of the water supply improvements from the effect of a general sanitation improvement. In some cases, notably that of Cincinnati and Philadelphia, there is not much doubt that the improvement in water supply explains the greater part of the reduction of typhoid fever. In the cases of Cleveland and Chicago it is quite possible that improvements in water supply played a somewhat smaller part in the reduction of typhoid fever death-rate than believed by some. However, these supplies were grossly polluted at intervals of short duration in earlier years.

The last set of curves, in the lower right-hand corner, shows the typhoid fever rate for four cities during the years noted on the curve. The particular feature to be noted is the extreme range of typhoid fever during the various parts of the year—low during the months of January and February, and very high during the summer months. The inference to be drawn is that the water supply, which does not change noticeably during the year, is to blame for only a relatively small part of the typhoid, and that the greater part is to be explained by other causes, such as the milk supplies, mosquitoes, flies, and other disease-spreading insects which thrive during the warmer months. It is worthy of note that the cities of this diagram come from the southern latitudes, where the effect of climate is more marked, especially as to the duration of the fly period.

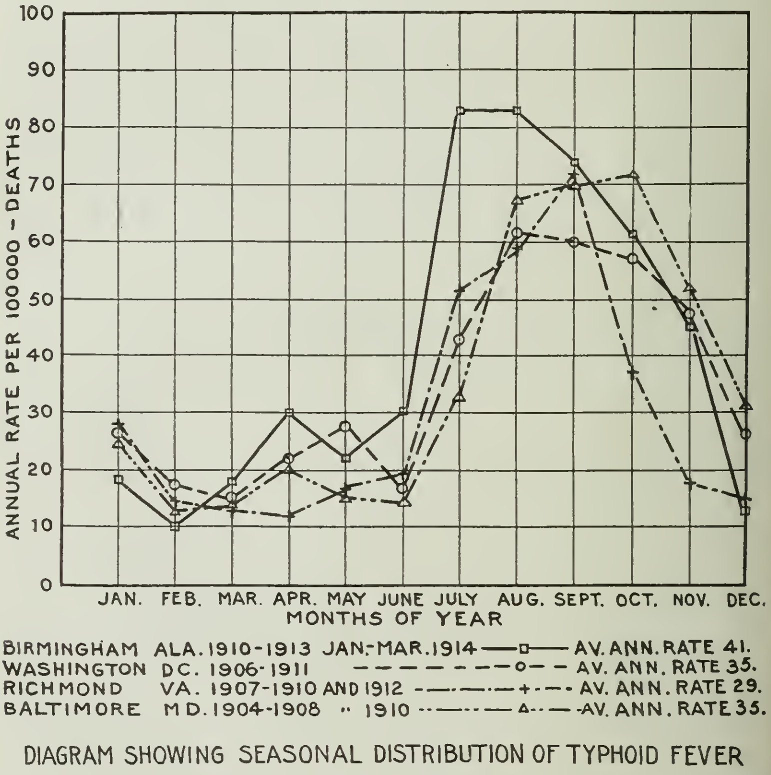
SEASONAL DISTRIBUTION OF TYPHOID FEVER.

It has been noted for many years that typhoid fever shows a marked difference in the cases found during the various seasons of the year. At certain times, notably the colder months, typhoid in some cities may be, and usually is, relatively low; while during the summer months, from July to October, very high typhoid fever rates are often noted. Such variations of typhoid fever incidence do not always, if ever, correspond to variations in the quality of water. The water supply may indeed vary in quality and be materially worse at some seasons of the year than others. It may often happen, however, that the times of bad quality of the water supply follow the times of high incidence of typhoid fever by an appreciable period. This may be taken to show rather definitely that the initial cause of the high typhoid fever rate at certain seasons of the year does not depend upon the water supply, but more likely the bad water supply may be the result of earlier typhoid fever conditions.

Fig. 5 shows in a little more detail the seasonal distribution of typhoid fever for the cities of Birmingham, Ala.; Washington, D. C.; Richmond, Va., and Baltimore, Md. The rates of typhoid fever indicated for the months from January to June average about twenty deaths per 100,000 population, and this figure is fairly uniform. Starting with the month of June and culminating usually with the month of August, but sometimes later, the typhoid fever deaths rapidly rise to a high figure of somewhere from seventy to eighty per 100,000. The real cause of such typhoid fever death-rates is to be found in the prevalence of flies under unfavorable sanitary conditions, such as unscreened privies and other unprotected sources of possible pollution, the prevalence of mosquitoes during the summer months, the possibility of bad milk during this season, and other similar sources of infection.

Fig. 6 illustrates the seasonal distribution of typhoid fever in the city of Jacksonville, Fla. The three curves given are for the three years, 1910, 1911, and 1912, 1910 being the solid line showing the highest rate, 1911 the dashed line showing the intermediate rate, and 1912 the dot-and-dash line showing the lowest rate. As in the previous diagram, the typhoid fever death-rate in the winter months was relatively low, around twenty per 100,000. During the warm summer months the typhoid fever cases and rates were very high. On the same reasoning as before noted, it is to be expected that these high summer rates were attributable to flies or other similar causes.

FIG. 5.



In this actual case, that of Jacksonville, it may be said that the proof of the pudding was in the eating, for the improvement shown by the three curves was effected on the theory above noted.

The heavy line shows the 1910 typhoid fever case rate, when all privies and water-closets were left in their ordinary loose, unscreened, and unprotected condition. In this year the rate ran up to 110 in the month of July. After this a start was made in cleaning up and making fly- and mosquito-proof all these water-closets and privies. The curve in 1911 shows the results of this work. The highest rate reported for the year 1911 was thirty in the month of June. During this summer, 1911, seventy-five per cent. of the closets were screened. In the year 1912 all the closets were screened and the highest rate recorded was eighteen in the month of June.

FIG. 6.

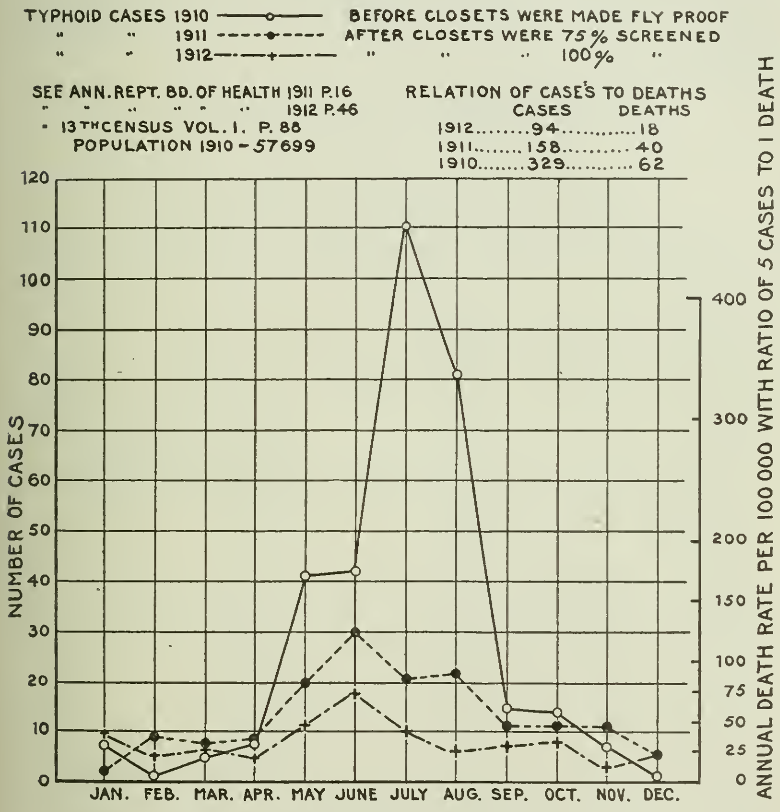


DIAGRAM SHOWING SEASONAL DISTRIBUTION OF TYPHOID FEVER
JACKSONVILLE - FLA.

Taking the whole year, we find that the typhoid cases were, for the years 1910, 1911, and 1912, 329, 158, and 94, respectively, and that the deaths for these years were 62, 40, and 18, respectively.

There exists very little doubt that all the improvements which have been made were the result only of the cleaning of the closets. It is not likely that the water supply in the city of Jacksonville, taken from very deep wells, was the cause of any typhoid fever.

THE BIRMINGHAM, ALA., WATER SUPPLY.

The relative significance of the bacterial content of water, of the coli content, the effect of water supplies on typhoid fever, as compared with the effect of flies, mosquitoes, milk, and other possible sources of typhoid fever infection, was under consideration in the case of the Birmingham Water Works Company, in which the speaker was interested early this year. This case depended on a complaint against the water supply received from the water works company on the ground that the water did not meet with the provisions of the franchise compact, which specified

> " that the water so furnished shall be clear, wholesome, and suitable for all domestic purposes, and ordinary manufacturing purposes."

From the sanitary standpoint this controversy did not involve the question of purity of the water in the raw condition. Essentially, it was a proposition of whether the opportunity for pollution of the raw water might have caused the raw water to become so polluted as to increase the load of work to be done by the filters beyond what might be reasonably caused by safe filtration practice, and so put a burden on the filters greater than that found in filter plants elsewhere, such as are producing what might be fairly termed pure and wholesome water, as that expression is used in the practical art of water supply and water purification.

The first step in the investigation of this problem was a visit to the watershed and an examination of local conditions. On going over the watershed of Five Mile Creek no seriously objectionable conditions were found. There were occasionally a few farmhouses. No villages existed on the watershed, and there was no sign of any direct sewage pollution. There remained, of course, the opportunity for indirect contamination, owing to soil wash, and the possibilities of the flushing of polluted matters by heavy rains into the feeders of the various streams above the head of the canal.

Considering the total population tributary to the water supply, and a comparison to see if an unduly large number of people discharge their waste into this water supply, Table VI shows a comparison of the Birmingham water supply with a number of other cities to show what is the density of population tributary to the watershed from which the city supply is derived.

TABLE VI.

POPULATION RESIDENT ON CERTAIN WATERSHEDS.

Note—Populations per square mile, except Birmingham, refer to 1900 population.

Name	Watershed		Population	Supply filtered
	Name	Area square mile		
Birmingham, Alabama	Five Mile Creek	16.2	35	Yes
Birmingham, Alabama	Main Cahaba	152	10	Yes
Birmingham, Alabama	East Cahaba	49	44	Yes
Boston, Massachusetts	Cochituate	18.7	775	No
Boston, Massachusetts	Sudbury	75.2	294	No
Boston, Massachusetts	Wachusetts	118.2	48	No
Lynn, Massachusetts	Saugus River	10.6	710	No
Springfield, Mass.	Little River	50.0	13	Yes
New Haven, Conn.	Lake Whitney	37.7	80	Yes
New Haven, Conn.	West River	13.6	50	No
New York, N. Y.	Croton	360.0	70	No
New York, N. Y.	Catskill	426.0	Winter 20	No
			Summer 36	No
Jersey City, N. J.	Rockaway	121.0	157	No
Paterson, N. J.	Passaic	773.0	22	Yes
Philadelphia, Pa.	Delaware	8186	30	Yes
Philadelphia, Pa.	Schuylkill	1915	98	Yes
Chester, Pa.	Delaware	10450	173	Yes
Harrisburg, Pa.	Susquehanna	24300	41	Yes
York, Pa.	Codorus	100	90	Yes
Wilkes-Barre, Pa.	Spring Brook	53	9	No
Wilkes-Barre, Pa.	Mill Creek	10	12	No
Wilkes-Barre, Pa.	Huntsville	15	27	Yes
Baltimore, Maryland	Jones Falls	39	154	No
Baltimore, Maryland	Gunpowder Creek	306	73	Building
Columbus, Ohio	Scioto	1050	70	Yes
Lawrence, Mass.	Merrimac	4634	69	Yes

It appears that the Five Mile Creek watershed contained a population of thirty-five to the square mile; the main Cahaba watershed a population of ten to the square mile; and the east Cahaba watershed a population of forty-four to the square mile. As compared with this, the old Boston watershed, Cochituate supply, has a population as high as 775 to the square mile; the Saugus River watershed, for Lynn, Mass., a population of 710; the Rockaway watershed, supplying the city of Jersey City, a population of 157 per square mile; the Delaware River watershed, supplying the city of Chester, 173 per square mile; the Merrimac watershed, supplying the city of Lawrence, a population of 69 per square mile.

So far as this particular item of population goes, it can readily be seen that for this case, that of Birmingham, the population on the watershed is among the lowest of those recorded, and that no great danger of pollution is to be expected on the score of excessive population.

In addition to the question of the number of people residing on the watershed, there is always the possibility of accidental pollution. This potential danger particularly leads to the needs for filtration and sterilization of water supply. The likelihood of such pollution is best measured by the presence of the *B. coli* in the water.

The records of the occurrence of *B. coli* in one cubic centimetre of water are shown in Table IV. The records are given for the four years from 1910 to 1913. The raw water shows roughly eighty per cent. positive occurrence of *B. coli* in one cubic centimetre of water by the presumptive test. This water is filtered before being supplied to the consumers. As compared with other water under similar conditions, the water is much the same as that of the Passaic River supplying the Little Falls plant of the New Jersey Water Company. It is somewhat better than the water of the Hudson River reaching the Albany filters, and somewhat better than the water of Brandywine Creek in the Wilmington filters, and somewhat better than the water supplied to London for filtration.

After filtration there was from 0 to 9.7 per cent. of positive tests showing *B. coli* in one cubic centimetre. This, as compared with other waters, under similar conditions, shows very well. It is somewhat better than some of the waters, somewhat worse than others.

On the basis of typhoid fever death-rates, which are often taken as an indicator of the quality of the water supply, it is to be noted that the city of Birmingham, based on the 1910 population, showed in 1910 a death-rate of forty-eight per 100,000 population; in 1911, forty-seven; in 1912, forty-two; in 1913, forty-five. These rates are, of course, relatively high, but compared with some twenty-nine southern cities of the larger size, having an aggregate population of something like two million people, the average of these twenty-nine cities showed an annual death-rate of fifty-seven per 100,000 population. In 1911, out of these twenty-nine southern cities, sixteen had a higher typhoid rate than Birmingham.

Birmingham conditions, as compared with other cities, have been illustrated in the data already shown. (See Fig. 5.) The explanation of the typhoid fever rate at Birmingham is not to be found in the water supply, but in the conditions of unprotected privies and other similar sources of pollution, whose infected contents are spread mostly by flies and mosquitoes.

A rather interesting feature of the water supply at Birmingham is the fact that the water from the Five Mile Creek watershed is sterilized after being filtered and shows no *B. coli* as delivered to the consumer. Water from the other watershed, the Cahaba, is not sterilized, but it is filtered, and shows an appreciable number of *B. coli*. Though the *B. coli* prevalence shown in one case is materially higher than in the other case, the typhoid fever of the two districts is roughly the same.

Certain parts of Birmingham are well sewered, but in these high-grade residential districts the prevalence of typhoid fever during the fly period was about as great as in the unsewered districts.

During the winter, or non-fly period of the year, the typhoid death-rate was low in all parts of the city.

It is logical to conclude that the occurrence of a moderately limited number of *B. coli* in any water means nothing as to the quality of the water, as opposed to a water which will show no *B. coli* whatever. It is only when the coli content becomes markedly high that it can be deduced that the water is, in consequence, unreasonably polluted.

As at Jacksonville, it was the fly and mosquito that transmitted typhoid at Birmingham.

The Density of Oxygen. A. F. O. GERMANN. (*Journal of Physical Chemistry,* vol. xix, No. 6.)—A brief historical survey of the more important determinations of oxygen is made, followed by a detailed account of the modern methods adopted in the Geneva Laboratory in the determination of gas densities, with particular reference to the purification of the gas used. An improvement in the globe method, as it has been developed in Geneva, is described, consisting of the simultaneous use of a number of barometers equal to the number of globes employed. The density of oxygen was revised, operating on gas furnished by the decomposition of potassium permanganate and purified by fractional distillation. Fifteen determinations led to the value of a "normal litre" under a pressure of 760 mm. of mercury at the temperature of melting ice at sea level in latitude 45° north: $L_n = 1.42906$. This value, taking into consideration the results of Morley and Rayleigh, leads to the value $L_n = 1.42905$, which represents, at the present time, the most probable value for the weight of the normal litre of oxygen.

The Purchase of Coal on a B. T. U. Basis. From "Coal for the Navy," J. O. RICHARDSON. (*Journal American Society of Naval Engineers,* vol. xvii, No. 2.)—The Navy Department has frequently been urged to purchase coal under strict specifications that provide that the purchase price shall be a certain figure for coal that shows a heating value of a certain number of British thermal units per pound; that coal which falls below or exceeds in calorific value this number shall be purchased at a price less or greater than the base price by an amount depending upon the number of B. T. U.'s below or above the standard. Theoretically this is an ideal way of purchasing coal, but practically it is very unsatisfactory, because it frequently happens that coal which in a laboratory test would be rated very high on a B. T. U. basis gives very poor results when burned in the furnace of marine boilers, and conversely.

In fact, one of the very best steaming coals in the market, and one which is largely used by sea-going steamers, would be barred from competition because of its lower B. T. U.'s than other first-class coals, and would therefore be forced to accept a lower price than such coals or abandon the navy trade, which it probably would. This coal, George's Creek, has long been recognized by marine engineers as one of the most satisfactory in the market. This method of purchasing coal would no doubt cause many disputes between the suppliers of coal and the Navy Department, and in the end would be unsatisfactory, because the navy is not buying so many heat units, but is buying high-grade coal that by actual use has been shown to be the best coal obtainable for naval boilers, and the suitability of the coal for the duty required should be the controlling factor in the purchase of coal for use on board naval vessels.

A RELATION CONCERNING THE DISTRIBUTION OF AN ELECTROLYTE BETWEEN WATER AND SOME SECOND SOLVENT AND ITS DISSOCIATION CONSTANT IN AQUEOUS SOLUTION.*

BY

HENRY JERMAIN MAUDE CREIGHTON,

Department of Chemistry, Swarthmore College.
Member of the Institute

INTRODUCTION.

ALTHOUGH the application of the laws of mass action to a very large series of reactions between ions and undissociated molecules has received excellent verification, and Ostwald's dilution law has been proved to hold for a large number of binary electrolytes, investigation has shown that it apparently fails in the case of the so-called strong electrolytes. Further, with many weak electrolytes, such as mesaconic acid,[1] α-chlorobutyric acid,[2] 2, 4, 5-trimethyl-benzoic acid,[3] and α-oximino-butyric acid,[4] to select a number of examples at random, the dissociation constant, as calculated by means of Ostwald's dilution law, is found to vary with dilution. Whether the degree of dissociation of these electrolytes is derived from the conductivity $\left(\alpha = \frac{\Lambda}{\Lambda_\infty}\right)$, or from the freezing-point lowering, $\alpha = \frac{d_o - d_t}{d_t\,(n - 1)}$, where d_o and d_t represent the observed and the theoretical (on the assumption of no dissociation) freezing-point lowerings, the values calculated for $\frac{\alpha^2 c^2}{(1 - \alpha)\,c}$ vary with concentration and deviate from the required constant. It is obvious, therefore, that either the dilution law does not correctly express the behavior of these electrolytes, or that the methods employed for the determination of their degree of dissociation gives incorrect values. This apparent break-down of the dilution law has been the subject of much discussion by Jahn, Arrhenius, and others, and opinions still differ widely [5] as to the cause of its inapplicability.

---

* Communicated by Professor Creighton.

[1] White, G. F., and H. C. Jones, *Amer. Chem. Journ.*, 44, 159 (1910).

[2] Lichty, D. M., *Ann. Chemie,* 319, 369 (1901)

[3] Pfaff, A., *Dis. Heidelberg,* (1897).

[4] Hantzsch, A., and A. Miolati, *Zeitschr. physik. Chem.*, 10, 1 (1892).

Since the dilution law holds for such a large number of electrolytes, and since its validity has been substantiated by thermochemical methods, solubility measurements, hydrolytic measurements, and measurements of reaction velocity, etc., it is probable that its failure, in certain cases, is due to the fact that the determination of the degree of dissociation by means of conductivity or freezing-point methods does not give correct results. The reasons for this are both physical and chemical. Variable friction of the ions; the existence in solution of interaction between the undissociated molecules and the ions, which counteracts their mutual independence;[6] the formation of inner complexes,[7] and the hydration of the ions [8] are all factors which tend to vitiate the values obtained from conductivity or freezing-point measurements for the degree of dissociation.

In view of the failure of conductivity or freezing-point measurements to give, in certain cases, correct results for the degree of dissociation, it is desirable to have recourse to other methods. Jahn [9] has attempted to determine the degree of dissociation by the measurement of concentration chains, but the method requires great precision and is hardly sufficiently sensitive where ordinary accuracy is required. Rothmund and Drucker [10] have determined the degree of dissociation of picric acid in aqueous solutions of different concentrations by measuring the distribution of the acid between water and benzene, and from the values obtained have shown that the value of the dissociation constant of picric acid varies slightly, but irregularly, with the concentration. On the other hand, the value for the dissociation constant of this acid is found to vary considerably with concentration, when values for the degree of dissociation, obtained by conductivity or freezing-point methods, are employed.

---

[5] *Jahrb. d. Elektrochemie,* 8, 102 (1902), and A. A. Noyes, *Technology Quarterly,* 17, No. 4 (Dec., 1904).

[6] Jahn, H., *Zeitschr. physik. Chem.,* 33, 545 (1900); 35, 1 (1900); 37, 490 (1901); 41, 257 (1902); Nernst, W., *Ibid.*. 38, 487 (1901).

[7] Bredig, G., *Zeitschr. physik. Chem.,* 13, 262 (1894); Noyes, A., *Ibid.,* 36, 63 (1901); Steele, *Ibid.,* 40, 722 (1902).

[8] Blitz, W., *Zeitschr. physik. Chem.,* 40, 217 (1902).

[9] Jahn. H., *loc. cit.*

[10] Rothmund, V., and K. Drucker, *Zeitschr. physik. Chem.,* 46, 827 (1903).

In the present communication a general formula has been developed by means of which it is possible to calculate the ionic concentrations of an electrolyte in aqueous solution from data obtained from the measurement of the distribution of the electrolyte between water and some second liquid phase. In the development of this formula it has been assumed that in aqueous solution the electrolyte obeys the dilution law, and that, in accordance with Nernst,[11] there is a constant distribution coefficient for the undissociated molecules of the electrolyte between the two liquid phases.

THEORETICAL.

When a substance is shaken up with two non-miscible solvents it is distributed between them in a definite manner[12] which depends upon its solubility in each of the solvents. The distribution coefficient, the ratio in which the solute is distributed between the two phases, depends not only upon the solubility of the solute, however, but also upon whether the molecular complexity of the solute is the same in the two solvents. When the molecular complexity is the same in both solvents the distribution coefficient is constant for a given temperature; but when the solute has a different molecular complexity in the two phases the simple distribution ratio varies with the concentration at a constant temperature.

The symbols employed in the remainder of the paper are as follows:

c, the total concentration of the solute in the aqueous phase in normal moles per litre;

b, the total concentration of the solute in the second phase in normal moles per litre;

α, the degree of dissociation of the solute in the aqueous phase;

x, the degree of association of the solute in the second phase;

n, the complexity of the associated molecules in the second phase;

δ, the ratio, $\frac{c}{b}$, *i.e.*, the simple distribution ratio;

K_1, the ratio of the distribution of the normal molecules between the two phases;

---

[11] Nernst, W., *Zeitschr. physik. Chemie*, 6, 36 (1890); 8, 110 (1891).

[12] Berthelot, M., and E. Jungfleisch, *Ann. chim. Phys.* [4], 24, 396 (1872); Jakowkin, A. A., *Zeitschr. physik. Chem.*, 18, 585 (1895); Ostwald, W., *Lehrbuch*, 2. Aufl., 1, 811.

K_2, the constant governing the equilibrium existing between the normal and associated molecules in the second phase, and

k, the dissociation constant of the simple molecules in the aqueous phase.

If, at a constant temperature, a binary electrolyte is shaken up with water and a second solvent in which it dissolves with the formation of simple and associated molecules, then, after a short time, the following equilibria will exist:

(1) between the ions of the electrolyte and the undissociated molecules in the aqueous phase;
(2) between the normal molecules in the aqueous phase and the normal molecules in the second liquid phase;
(3) between the normal and associated molecules in the second liquid phase.

The first of these equilibria is governed by Ostwald's dilution law:

$$k = \frac{\text{anion concentration} \times \text{cathion concentration}}{\text{concentration of the undissociated molecules}} = \frac{\alpha^2 c^2}{(1-\alpha)c}. \qquad (1)$$

The second equilibrium is governed by the equation,

$$K_1 = \frac{\text{conc. of normal molecules in aqueous phase}}{\text{conc. of normal molecules in second phase}} = \frac{c(1-\alpha)}{b(1-x)}. \qquad (2)$$

The third equilibrium is governed by the equation,

$$K_2 = \frac{\text{conc. of normal molecules in second phase}}{\text{conc. of associated molecules in second phase}} = \frac{b(1-x)}{\sqrt[n]{bx}}. \qquad (3)$$

Let the concentration of the undissociated molecules in the aqueous phase be z, *i.e.*, $c(1-\alpha) = z$. Then from equation (2) it follows that

$$z = K_1 b(1-x), \qquad (4)$$

and by combining equations (3) and (4)

$$z = K_1 K_2 \sqrt[n]{bx} = K_3 \sqrt[n]{bx}. \qquad (5)$$

On multiplying equation (4) by K_3 and equation (5) by K_1, we obtain

$$K_3 z = K_1 K_3 [b(1-x)], \qquad (6)$$

and

$$K_1 z = K_1 K_3 \sqrt[n]{bx}\,. \qquad (7)$$

By adding equations (6) and (7),

$$z = \frac{K_1K_3}{K_1+K_3}\left[b(1-x)+\sqrt[n]{bx}\right], \tag{8}$$

$$= K\left[b(1-x)+\sqrt[n]{bx}\right]; \tag{9}$$

and for a second concentration,

$$z' = K\left[b'(1-x')+\sqrt[n]{b'x'}\right]. \tag{10}$$

By dividing equation (9) by equation (10), we obtain

$$\frac{z}{z'} = \left[\frac{b(1-x)+\sqrt[n]{bx}}{b'(1-x')+\sqrt[n]{b'x'}}\right]. \tag{11}$$

Therefore,

$$z' = z\left[\frac{b'(1-x')+\sqrt[n]{b'x'}}{b(1-x)+\sqrt[n]{bx}}\right]. \tag{12}$$

On putting

$$p = \left[\frac{b'(1-x')+\sqrt[n]{b'x'}}{b(1-x)+\sqrt[n]{bx}}\right], \tag{13}$$

equation (12) becomes

$$z' = zp\ . \tag{14}$$

Since in the aqueous phase the concentration of the anions or cathions is equal to the total concentration minus the concentration of the undissociated molecules, *i.e.*,

$$\alpha c = c - c(1-\alpha) = c - z,$$

equation (1) may be written

$$\frac{(c-z)^2}{z} = k = \frac{(c'-z')^2}{z'}, \tag{15}$$

or

$$\frac{(c-z)}{\sqrt{z}} = \frac{(c'-z')}{\sqrt{z'}}. \tag{16}$$

On substituting in equation (16) the value given for z' in equation (14), we obtain

$$\frac{(c-z)}{\sqrt{z}} = \frac{(c'-zp)}{\sqrt{zp}}, \tag{17}$$

whence

$$z = \frac{c'-c\sqrt{p}}{p-\sqrt{p}}\ . \tag{18}$$

On substituting in equation (18) the value given in equation (13) for p, we obtain

$$z = \left[\frac{c' - c\sqrt{\dfrac{b'(1-x') + \sqrt[n]{b'x'}}{b(1-x) + \sqrt[n]{bx}}}}{\left[\dfrac{b'(1-x') + \sqrt[n]{b'x'}}{b(1-x) + \sqrt[n]{bx}}\right] - \sqrt{\dfrac{b'(1-x') + \sqrt[n]{b'x'}}{b(1-x) + \sqrt[n]{bx}}}} \right] \tag{19}$$

By means of the general equation (19) the concentration of the undissociated molecules in the aqueous phase may be calculated, even when the solute is present in the second phase as a mixture of normal and associated molecules. When association of the normal molecules in the second phase does not incur, *i.e.*, when $x = 0$, equation (19) reduces to

$$z = \frac{c' - c\sqrt{\dfrac{b'}{b}}}{\dfrac{b'}{b} - \sqrt{\dfrac{b'}{b}}}. \tag{20}$$

If, on the other hand, the association of the molecules in the second phase is complete, *i.e.*, if $x = 1$, equation (19) becomes

$$z = \frac{c' - c\sqrt[2n]{\dfrac{b'}{b}}}{\sqrt{\dfrac{b'}{b}} - \sqrt[2n]{\dfrac{b'}{b}}}. \tag{21}$$

It is evident from equation (19) that, when the solute is present in the second liquid phase as a mixture of normal and associated molecules, it is necessary that the degree of association, x, of the normal molecules be known, in order to calculate the concentration, z, of the undissociated molecules in the aqueous phase. The degree of association of the normal molecules in the second liquid phase may be obtained by means of measurements of the freezing-point lowering produced in the second solvent by the solute. The degree of association is given by the equation,

$$x = \frac{M_o - M_t}{M_o\left(1 - \dfrac{1}{n}\right)}, \tag{22}$$

where M_o represents the molar weight calculated from the observed freezing-point lowering, and M_t the molar weight calculated from the chemical formula of the solute.

EXPERIMENTAL VERIFICATION OF EQUATION (19).

In order to test the validity of equation (19), determinations have been made of the distribution of benzoic acid between water and benzene. Since it has been shown,[13] in the case of some electrolytes, that the distribution ratio varies with temperature, the distribution of benzoic acid has been measured at 6 ± 0.1°, a temperature which lies very close to the temperature at which the x values for benzoic acid in benzene have been determined by the freezing-point method.

Thiophene free benzene (*Kahlbaum zur Analyse*) was used in the distribution experiments. The benzene solutions of benzoic acid were mixed with an equal volume of "conductivity" water, and the mixture placed in suitable bottles, which were agitated in a thermostat for several hours, at the end of which time the bottles were removed from the agitation apparatus and allowed to stand in the thermostat until complete separation of the two liquid phases had taken place. Portions of the aqueous and benzene layers were then removed and analyzed with standard sodium hydroxide solution which was prepared from pure metallic sodium. Table I gives the results of the distribution measurements made with benzoic acid at 6°.

TABLE I.

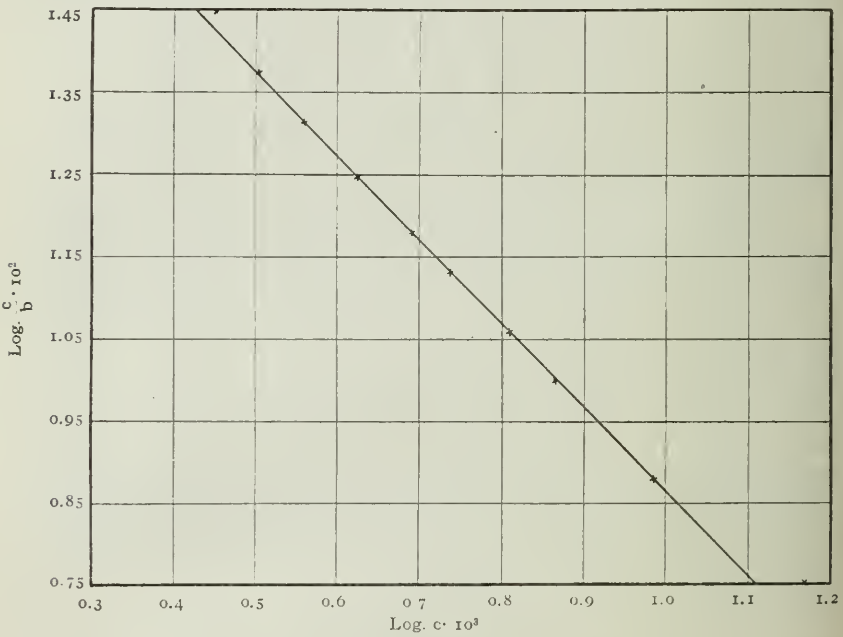
No.	Concentration of benzoic acid in moles per litre		Simple distribution ratio
	Aqueous phase c	Benzene phase b	δ
1	0.00215	0.00754	0.2851
2	0.003291	0.01565	0.2103
3	0.004349	0.02750	0.1581
4	0.004930	0.03551	0.1388
5	0.005794	0.04951	0.1170
6	0.006440	0.06158	0.1046
7	0.007490	0.08352	0.0897
8	0.008743	0.1144	0.0764
9	0.009930	0.1480	0.0671
10	0.01139	0.1951	0.0584

---

[13] Hantzsch, A., and A. Vagt, *Zeitschr. physik. Chem.*, 38, 705 (1901).

As the variation in the values of the simple distribution ratio in the foregoing table indicates, the benzoic acid exists partially as associated molecules in the benzene phase. The decrease in the value of δ with increase in concentration is linear, as is shown by the curve in Fig. 1, where the values of $\log c \times 10^3$ are plotted on the axis of abscissæ against the values of $\log \frac{c}{b} \times 10^2$ on the axis of ordinates. With the exception of the values for the initial and final concentrations, all the points lie on a straight line.

FIG. 1.



In order to determine the degree of association, x, of the normal benzoic acid molecules in benzene, measurements were made of the freezing-point depressions of benzene produced by the same concentrations of benzoic acid employed in the foregoing distribution experiments. During the process of freezing, the solutions of benzoic acid were stirred by means of a platinum-iridium stirrer operated by an electromagnet.[14] The results of the freezing-point depression measurements are recorded in Table II.

---

[14] Beckmann, E., *Zeitschr. physik. Chem.*, 44, 174 (1903).

TABLE II.

Concentration of benzoic acid		Freezing-point depression ° C	Observed molar weight M^o	Degree of association ($n=2$) x
Grammes acid per 100 grammes benzene	Moles acid per 1000 c.c. benzene solution at 6°			
0.2136	0.01565	0.049	218	0.881
0.3754	0.02750	0.085	221	0.896
0.4847	0.03551	0.109	222	0.901
0.6758	0.04951	0.151	224	0.911
0.8406	0.06158	0.187	225	0.916
1.1388	0.08352	0.251	227	0.925
1.5600	0.1144	0.341	229	0.934
2.0180	0.1480	0.439	230	0.939
2.6623	0.1951	0.574	232	0.948

The values for the observed molar weight, given in the foregoing table, agree excellently with those determined by Beckmann.[15]

TABLE III.

$$z = \frac{c' - c\sqrt{p}}{p - \sqrt{p}}.$$

No.	3	4	5	6	7	8	9	10
2	3.914	4.491	5.255	5.858	6.848	8.026	9.160	10.53
3	.....	4.593	5.227	5.791	6.819	7.980	9.125	10.53
4	4.026	.....	5.065	5.673	6.713	7.960	9.058	10.47
5	3.859	4.254	.....	5.658	6.770	7.938	9.087	10.51
6	3.828	4.259	5.057	.....	6.875	7.984	9.129	10.53
7	3.840	4.313	5.161	5.863	.....	7.918	9.073	10.51
8	3.830	4.318	5.154	5.803	6.743	.....	9.117	10.56
9	3.826	4.321	5.157	5.800	6.762	7.994	.....	10.61
10	3.833	4.337	5.175	5.806	6.788	8.018	9.183	.....

The concentration, z, of the undissociated molecules of benzoic acid in the aqueous phase may now be calculated by means of equation (19), from the data recorded in Tables I and II. Table III contains the values of z calculated by means of this equation. In the vertical columns, with the exception of the first, are represented the values of z which correspond to that total concentration, c, indicated by the numerals running horizontally along the top of the table. The numerals in the first vertical column represent the concentrations, c', with which a particular concentration, c, has been combined in order to calculate z. The values given for z in Table III have all been multiplied by 10^3. The numerals 2–10, correspond to those employed in Table I.

---

[15] Beckmann, E., *Zeitschr. physik. Chem.*, 2, 715 (1888).

If the relation between the undissociated molecules in the aqueous phase and the normal and associated molecules in the benzene phase is correctly expressed by equation (19), it follows that the values for z in each vertical column should be constant. Although the values for z in the different columns of Table III vary slightly, they are sufficiently constant to substantiate the validity of the equation. It should be pointed out that small variations in the values for c and b, as determined by analysis, produce relatively large changes in the values calculated for z. It is evident, therefore, that in order to obtain even approximately correct values for z it is necessary that c and b be determined with the highest possible degree of accuracy.

Values for the coefficient of the distribution of the normal molecules of benzoic acid between water and benzene at 6° are recorded in Table IV.

TABLE IV.

$$K_1 = \frac{c(1-a)}{b(1-x)} = \frac{z}{b(1-x)}.$$

No.	3	4	5	6	7	8	9	10
2	1.368	1.278	1.193	1.132	1.093	1.063	1.015	1.038
3	.....	1.307	1.186	1.120	1.088	1.057	1.011	1.038
4	1.408	.....	1.150	1.096	1.072	1.054	1.003	1.032
5	1.349	1.210	.....	1.093	1.081	1.052	1.007	1.036
6	1.338	1.215	1.148	.....	1.098	1.058	1.011	1.038
7	1.343	1.227	1.171	1.133	.....	1.049	1.005	1.036
8	1.339	1.228	1.170	1.122	1.076	.....	1.010	1.041
9	1.338	1.230	1.170	1.121	1.079	1.059	.....	1.046
10	1.340	1.234	1.174	1.133	1.083	1.062	1.017	.....
Mean.	1.353	1.241	1.170	1.119	1.084	1.057	1.010	1.038

As is to be expected, with the exception of the values for the third and fourth concentrations, the mean values for the coefficient of the distribution of benzoic acid between water and benzene are fairly constant. By taking the average of the mean values in the foregoing table, the value 1.134 is obtained for the coefficient of distribution.

In Table V are given the values of the dissociation constant of benzoic acid, which have been calculated by means of Ostwald's dilution law from the values of c and z contained in Tables I and III. All the values in this table have been multiplied by 10^5.

TABLE V.

$$k = \frac{(c-z)^2}{z}.$$

No.	3	4	5	6	7	8	9	10
2	4.84	4.29	5.53	5.92	6.02	6.40	6.47	7.03
3	....	2.47	6.15	7.27	6.60	7.30	7.10	7.03
4	2.59	.....	10.49	10.37	8.99	8.86	8.39	8.09
5	6.22	10.72	.....	10.81	7.66	8.16	7.82	7.37
6	7.09	10.57	10.74	....	5.50	7.22	7.03	7.03
7	6.75	8.83	7.76	5.68	....	8.60	8.10	7.37
8	7.03	8.68	7.95	6.99	8.27	....	7.25	6.52
9	7.15	8.58	7.87	7.06	7.84	7.02	....	5.72
10	7.11	8.11	7.41	6.92	7.26	6.56	6.08	....
Mean.	6.10	7.78	7.11	7.63	7.27	7.52	7.28	7.02

It will be seen that the calculated values for k in each column of Table V vary slightly and irregularly about the mean value. By taking the average of the means, the value 7.2×10^{-5} is obtained for the dissociation constant of benzoic acid in water at 6°. By means of electrical conductivity measurements, White and Jones [16] have found that the dissociation constant of benzoic acid in water is 6.2×10^{-5} at 0°, and 6.7×10^{-5} at 15.8°; while Salm [17] obtained the value 7.2×10^{-5} at 18° by a colorimetric method. It is evident, therefore, that, while the method described in this paper gives a value for the dissociation constant which is somewhat higher than that obtained by the conductivity method, the agreement between the values obtained by the two methods is sufficiently close to demonstrate that approximate values for the dissociation constant may be calculated from the distribution data by means of the formula derived in this paper. Although the distribution method for the determination of the dissociation constant of electrolytes cannot compete with the conductivity method in most cases, on account of the relatively large experimental errors involved and the high degree of accuracy necessary, its use is suggested in those cases where the value of the dissociation constant of an electrolyte, as determined by the conductivity method, is found to undergo considerable variation with change in concentration.

---

[16] White, G. F., and H. C. Jones, *Amer. Chem. Journ.*, 44, 159 (1910).

[17] Salm, E., *Zeitschr. physik.Chem.*, 63, 83 (1908).

SUMMARY.

1. A general formula has been developed for the calculation of the concentration of the undissociated molecules of an electrolyte in water by means of data obtained by the measurement of the distribution of the electrolyte between water and a second liquid phase. The formula takes into consideration the possibility of association of the electrolyte in the second liquid phase.

2. In order to test the validity of the formula, measurements of the distribution of benzoic acid between water and benzene have been carried out at 6°, and, from the data obtained, the concentration of the undissociated molecules of benzoic acid in the aqueous phase has been calculated. From these values, a mean value, 7.21×10^{-5}, has been obtained for the dissociation constant of benzoic acid in water at 6°.

3. Although the foregoing value for the dissociation constant of benzoic acid in water is somewhat higher than that obtained by the conductivity method, the use of the distribution method for obtaining an approximate value for the dissociation constant of an electrolyte, in those cases where the value as determined by the conductivity method varies considerably with concentration, is suggested.

DEPARTMENT OF CHEMISTRY,
Swarthmore College,
Swarthmore, Pa.,
May 24, 1915.

CONDITIONS AFFECTING THE SUCCESS OF MAIN LINE ELECTRIFICATION.*

BY

W. S. MURRAY,
Consulting Engineer, New York, New Haven and Hartford Railroad Company.
Member of the Institute.

DISCUSSION

Mr. Alfred W. Gibbs (*Chief Mechanical Engineer, The Pennsylvania Railroad Company*).—While recognizing the merit of the paper and its frankness throughout, I call attention to a few points where it is not sufficiently explicit, or with which I do not agree.

As for the first, I allude especially to the tendency of cities to require electrification through their limits, usually for the purpose of eliminating smoke. While it is true that the inhabitants of a small community may be as much inconvenienced as those of the largest city, it must be recognized that this demand, if fully carried out, means the establishment of as many steam locomotive terminals as there are separate lines of road leading into the city, the alternative to this being the electrification of the whole line. These local terminals would involve not only a heavy capital outlay, but a continued charge to expenses, due to the increased cost of the additional organizations and the less efficient use of the labor and equipment. This is properly a charge to electrification, and a heavy one.

Mr. Murray is not quite fair in his criticism of the engineers who are responsible for the introduction of the direct-current system into the large terminals in New York City. It must be remembered that a long period of agitation had preceded the determination to electrify. The electrification was to avoid the objection to steam operation into the heart of a great city, and the first condition was that it should be a success from an operating standpoint. Is it surprising that the engineers in charge should turn to methods which had been thoroughly tried out? In at least one case the proposal to adopt the alternating-current system of transmission was not seriously advanced until after a very large outlay had been incurred for direct-current operation, a large part of which would have had to be absolutely thrown away to introduce the new system—and that untried on a large scale in this country. It must be remembered, further, that any serious operating failure would have jeopardized the whole investment and put back electrification for years. The engineers did not then have to settle the question of future extension of electrification. There was not then, and there may not be for a long time, any necessity to consider the question of future road electrification. By that time the air will have cleared considerably. It must be admitted that the operating results in New York have fully justified the engineers responsible.

---

* Concluded from page 557, May issue of this Journal.

I criticise, also, the statement that one pound of coal burned under the boiler of a central power plant will develop twice the drawbar power that the same amount of coal will produce when burned in a locomotive firebox. Proper allowance has not been made for the improvement in the modern steam locomotive with more liberal boiler capacity and with superheat. As an example, I have a record of coal per drawbar horse-power for 27 tests of one locomotive on the locomotive testing plant at Altoona. It shows:

2.5 to 3 pounds	12 tests
3 to 3.5 pounds	7 tests
3.5 to 4 pounds	3 tests
4 to 4.5 pounds	1 test
4.5 to 5 pounds	4 tests

These are the rates when running, added to which are certain standby losses at terminals.

The figures for the coal per kilowatt-hour at Cos Cob, as given by Mr. Murray, when reduced to drawbar horse-power for the locomotive, do not justify the statement of relative efficiency.

There is great difficulty in arriving at a fair basis of comparison between steam and electric operation. For road locomotives and through electric operation the problem is the simplest. For switching service, where the steam locomotive may waste more steam at the safety valve that it uses in the cylinders, the problem is very different. This part of the paper covers one of the greatest advantages of the electric operation.

In the table giving the cost of power the total costs are not given. Operation and maintenance account for 0.511 cent; fixed charges, including taxes and insurance, amount to 0.180 cent.

No allowance is made for depreciation in the form of obsolescence in the power-house and its equipment. From data of somewhat similar power-houses, I should say that the fixed overhead charge, including depreciation, would be nearly double the figure given, say 0.35 or 0.4 cent, in the inverse ratio to the output. I regard this part of the expense account as a most important part of the accounting; otherwise, the time comes with startling suddenness when you have obsolete equipment, with insufficient reserve to replace it.

While making these criticisms, it is but fair to recognize the courage of those responsible for the electrifications described in this paper and preceding ones.

The paper is, in my judgment, very instructive, and all the more so because no claim is made for the 100 per cent. perfection which we never realize.

MR. GEORGE R. HENDERSON (*The Baldwin Locomotive Works*).—Mr. Murray's paper on Main Line Electrification will stand out as a " classic," giving, as it does, actual figures for cost of operation on an alternating-current line. Several years ago Mr. W. J. Wilgus gave similar data for the direct-current lines of the New York Central. Both of these papers show that " uniformity " of traffic is just as important as " density " of traffic, otherwise the overhead charges of the power plant, which must be abnormally large, will more than " eat up " any saving due to fuel consumption, repairs, and labor, as the plant must take care of *peak loads,* and these can only be " smoothed out " when the traffic is uniform. As one hundred dollars per kilowatt will hardly cover power-house and transmission lines, the importance of this observation will be obvious.

The fuel saving is stated as 50 per cent. for a fixed drawbar pull, yet it must be borne in mind that this comparison is made with the old type of saturated steam locomotives, and modern steam engines, fitted with superheaters, will reduce this ratio very considerably, say to 65 per cent. the amount of coal for such a locomotive as would be built to-day.

The fact that electric locomotives cost about three times as much as a steam locomotive of similar power must not be overlooked, also the flexibility of service of the latter is very important, as it may be transferred to any division desired owing to traffic conditions, and is not tied to a particular section whose limits are the lengths of the conductors leading from the power-house. This is of prime importance to roads carrying intermittent business, such as live stock, which may have a week's work consolidated into a single night, or on the ore ranges in Michigan, which deliver cargoes to lake boats only during the period of navigation. Under such conditions the overhead charges would be out of all proportion to the work accomplished, and the electric locomotives would be idle a large part of the time, as they could be used only on electrified divisions.

However, we are glad to note that Mr. Murray does not wildly and enthusiastically proclaim electrification a " sure cure " for all evils, regardless of environment and operating conditions, as did some electrical experts a few years ago, and the conservatism for which he pleads will surely benefit the whole problem of electrification, by insuring the large expenditures chargeable to capital only where they will produce remunerative returns from operation.

MR. E. H. MCHENRY (*McHenry & Murray,* Engineers, New Haven, Conn.).—Mr. Murray strikes a very important key-note in the opening paragraphs of his interesting paper, in referring to the two-fold necessity for satisfying the requirements of both the public and the railroad as the touchstone of success.

The first requisite in the interest of the public may be fairly claimed as already satisfied, but the greater task of insuring adequate returns to the railroads upon the large capital investments required for conversion from steam to electric traction is as yet far removed from the state of an exact science. As stated by Mr. Murray, there are many places where electric traction could now be installed with profit, but the ability and ingenuity of the engineers will be taxed to the utmost degree in further widening and enlarging the present commercial field of application. The progress of recent years in the development of the art all tends in the right direction, as with experience and a clearer perception of the governing principles, the commercial efficiency of the invested capital grows greater, and there is no reason to doubt that the past progress will be continued in the future, with the result of greatly extending the present limits. With the growing tendency toward the consolidation of the best features of all the divergent systems into one system of greatest combined merit, the so-called war of the systems is already nearly at an end, and even now it will be found that there is more to be gained by a study of the possibilities afforded by the new method of train propulsion in securing the closest adaptation of its many points of merit to the operating requirements than by any probable difference between rival systems. There is room for much optimism in this general direction, although many cases will arise of special difficulty, in which the community or that part of the public most benefited by the improved facilities are least able or least willing to pay the cost of the service, as in the case of communities using costly passenger terminals, and unless some satisfactory method can be devised for spreading the cost of such service over a city or a state substantially in the form of a tax, no practical solution of this difficult problem will be clearly apparent. In electrification, as in all other branches of engineering, the highest art will be shown by " the ability to make a dollar earn the most interest."

MR. C. RENSHAW (*Westinghouse Electric and Manufacturing Company*).—As a traveller climbing a mountain will often not realize the height he has attained until, pausing, he looks back over the route he has traversed, so, although from the beginning I have followed the New Haven electrification through its various stages, the summary which Mr. Murray gives of the electric mileage, equipment, and activity to which the road has now attained has impressed me particularly.

The application of electricity to the operation of every class of passenger, freight, and shifting service on an entire engine division of one of the busiest trunk line railroads of the country is an achievement that stands without a parallel in the entire world. It should be particularly gratifying, not only to those who are interested in electrical matters, but to the general public as well, that the undertaking is proving an economic as well as a technical success.

No less notable than the achievement itself has been the policy of the railway company in giving so freely to the engineering public the full results of its investigations and experience, not only with regard to its successes, but—what is of perhaps greater utility and certainly of greater rarity—with regard to its difficulties. The costs and other data which Mr. Murray has included in this paper form a valuable addition to the previous contributions which he has made.

As might be expected from experience with any original enterprise, Mr. Murray estimates that the electrical plant of the New Haven road, with the ten years' experience in construction and operation, now available, could be reproduced to-day for not more than 60 per cent. of its original cost. It should be gratifying to all, however, that he also states the financial return will ultimately be sufficient to justify the actual expenditure to date, so that the courageous pioneer will not be a loser. Some road, he says, had to make the first break into the dark, but, from the data assembled, future results in the application of electricity in heavy trunk line territory can be predicated on assembled facts and not predicted from hypothetical analysis.

In considering the economies over steam operation, by means of which electrification can justify the investment which it requires, Mr. Murray puts the matter very simply by pointing out that these economies are normally of three kinds; *i.e.,* saving in fuel, saving in motive power maintenance and repairs, and saving in train miles.

Broadly speaking, he says the costs of the first two items under electrification will be one-half the cost under steam operation. The saving in train miles, however, depends very largely on local conditions and cannot well be generalized. Success in electrification, therefore, is primarily dependent upon density of traffic. This reduces the matter pretty well to its lowest terms and should help eliminate some of the mystery with which the savings to be effected by electrification have apparently heretofore been surrounded in the minds of many railroad operating officials.

A detail in the paper which deserves particular comment is the fact which is pointed out that an electric locomotive, like an over-willing horse, may work itself to destruction if permitted to do so. While it is perfectly possible to keep the cost of maintenance and repairs at one-half those of steam locomotives, under conditions most favorable to steam operation, Mr. Murray says it is only by the most rigorous and careful inspection and conformity to proper rules of operation that this can be done.

This fact is one of the most difficult to impress upon the minds of steam railroad operators, and it is to be hoped that the figures of 8.6 and 10.6 cents per mile for the maintenance and repairs of the general average of New Haven locomotives, as compared to the average of 3.96 cents per mile for the ten locomotives which have been properly overhauled, will have some effect in bringing about a more thorough realization of this important matter. Incidentally, this figure for the maintenance and repairs of ten locomotives, making 466,524 miles in the seventh year of their age, is a remarkable commentary on the reliability of such equipment when handled intelligently.

The paradoxical action of heavy freight trains in steadying the power-house load instead of causing an increase in the peaks, as it was feared they would do, is also of interest. The fact that these trains, by dropping the voltage slightly, when drawing heavy accelerating currents, naturally cause other trains moving at high speed in the neighborhood to automatically reduce their power requirements, is readily appreciated when once noted, but is one of the many items brought out by actual experience which are often overlooked in advance calculations. Fortunately, in this case the unforeseen item is one which produces a favorable rather than an unfavorable effect on the operation of the system.

Many other items which Mr. Murray has set forth are also worthy of comment, and the entire paper forms a valuable contribution to the subject. We hope that it may serve as an inspiration to other engineers in active touch with the operation of similar properties to present their experiences with equal freedom for the general benefit of the art.

MR. F. E. WYNNE (*Westinghouse Electric and Manufacturing Company,* East Pittsburgh).—Mr. Murray's paper is a very valuable contribution to the literature of electric railroading, not only on account of the operating data which it contains, but because of its clear exposition of the broad principles to be considered in deciding whether an electrification will be successful. In the past electrical engineers have been accused (and to some extent rightfully so) of advocating wholesale electrification of steam railroads without regard to the measure of success which might be expected. It is therefore very pleasing to find a representative electrical engineer taking the stand that an electrification is only justified when it is an assured success from the standpoint of all parties concerned.

The figure of $15,000,000 given as the expenditure for electrification of the New Haven Railroad to date indicates that the expenditure has been $120,000 per unit of motive power and $30,000 per mile of single track. Complete electrification of the New York-New Haven Division will be accomplished without additional expenditure for trolley construction (which is a very large proportion of the total), and consequently these unit figures will be somewhat changed. The total expenditure per unit of motive power will gradually decrease and that per mile of single track will increase to some extent because of the larger number of electric engines in service without increase in the mileage of the electric zone.

The further statement that the present plant could be reproduced at the present time with better operating results for not more than 60 per cent. of the actual cost to date indicates that for an installation similar to the New Haven the total cost may be made less than $70,000 per unit of motive power, while the cost per mile of single track will be in the neighborhood of $20,000. These figures, as noted by Mr. Murray, represent the cash outlay, and in determining the net cost of electrification they will be reduced by the credits for steam equipment replaced, etc.

The figures given for mileage show that passenger locomotives average approximately 170 miles each daily, and that only 22 per cent. of the total number of passenger trains have the full run of seventy-three miles. This daily mileage per locomotive is comparable to that secured from electric cars operating in rapid transit and heavy interurban service. It therefore seems reasonable to assume that when all through trains are electrically operated the average daily mileage per locomotive may be materially increased.

Similarly the multiple-unit motor cars show an average of eighty-four miles each daily. This is relatively low, but is undoubtedly due to the fact that local trains are bunched in the morning and evening rush hours to a greater extent than is ordinarily found. This low mileage, together with the fact that over half of the total multiple-unit trains operate with only one trailer per motor car, indicates that the railroad is not yet getting the full benefit of the rather large equipments on the motor cars.

The figures given in connection with the operation of the switching engines illustrate the remarkable reliability and operating economy of electric locomotives in this particular class of service. Such results lead us to believe that the field for the electrification of railroad yards is a large one and that considerable progress in this direction will follow a full appreciation of the success which may be expected. As density of traffic is one of the largest factors in determining the advisability of electrifying main lines, so the desirability of yard electrification will largely be determined by the degree of congestion existing. In such installation the initial expense may be reduced to a minimum where central station power is available.

Mr. Murray states that electrification very quickly increased the reliability of operation to some three or four times that of the steam operation it replaced. We do not altogether understand what is the measure of reliability used in making this comparison, but assume he means that the number of failures were from one-third to one-fourth as many as were encountered during steam operation for a similar period.

In connection with Mr. Murray's statement that maintenance and repairs on electric locomotives amount to approximately one-half those required for steam locomotives with equal weight on drivers, I should like to ask whether operation in equal service also should not be part of the basis of comparison.

The remarks regarding the differences in the natures of electric and steam engines are particularly pertinent, and Mr. Murray's plea for electrically-trained men in the administrative department of electrified steam railroads points out one of the things which is of the highest importance in securing the fullest measure of success in electrifications.

It is interesting to note the results secured in connection with energy consumption, as these closely check the accuracy of calculations made in connection with this service, thus illustrating the fact that the energy consumption with electric operation can be very closely predetermined where trains are operated on a steam railroad basis; that is with definite schedules and definite stops. The figures given show further how rapidly the consumption of energy increases with the increasing number of stops as indicated by the several classes of service. Since the electrical equipment is merely apparatus for converting electrical into mechanical energy, it follows that with increased unit energy consumption increased work is required of the electrical equipment, and therefore electric locomotives will safely handle much greater tonnages in through service than in local service. They will also handle greater tonnages at moderate speeds than can be operated at high speeds.

The information regarding the improvement of load factor and smoothing out of the curve of power station output with the addition of trains (even though those trains were comparatively heavy) illustrates a principle which has been found to exist in connection with city and interurban electric railways; namely, that the peak load on the system increases less rapidly than in proportion to the increase in number of cars or trains operated. However, in city and interurban systems this is probably due more to the fact that as the number of cars operated increases a smaller proportion of the total are starting simultaneously, rather than to the fly-wheel effect of the moving cars. We are inclined to the opinion that with further increase in the number of trains electrically operated by the New Haven Railroad some benefit in the improvement of load factor and reduction of peaks will be secured from this source, as well as from the fly-wheel effect of the moving trains.

The reduction in cost of the trolley construction which has been made since the initial installation shows great progress in the right direction. However, we believe that it is not yet sufficiently low to represent maximum all-around economy. This belief is strengthened somewhat by Mr. Murray's statement of the extraordinary reliability of the overhead construction in stormy weather. This great degree of reliability leads us to question whether part of the cost of the overhead construction may not be due to its being designed with an unnecessarily great factor of safety.

In connection with Table 17, only interest, taxes, and insurance are specified as fixed charges. I should like to ask whether a depreciation allowance is included in the figures given.

I feel that the Institute is to be congratulated upon securing the presentation of such an able paper, and trust that its author may continue to make public his valuable data regarding the principles of railroad electrification, to the end that electric operation of steam railroads may be extended and may be attended by the greatest success.

PHILIP TORCHIO (*New York Edison Company*).—The growth of large electrical undertakings has been the evolution from small beginnings. In the case of railroad electrification, however, the problem has been quite different. With an established heavy traffic which does not allow of interruption or delays, a new system of traction is to be substituted, requiring radical structural changes all along the line and an entire new system of power generation and distribution.

The engineers confronted with the problem have attacked it in a comprehensive and thorough manner, developing complete systems as self-sustaining and autonomous as the progress of the art allowed them to accomplish at the time. Mr. Murray has described the operation of a system which really went a step further and anticipated the progress of the art by many years. The importance of this epoch-making " experiment " is naturally immensely valuable.

The author emphasizes the point that the experience of the New Haven will benefit the other railroads in solving their problems of electrification. In this connection I wish to call attention to the item of investments in power-houses and power-transmitting lines, which in all the original electrifications were assumed as a necessary part of the equipment, but which in late years the railroads have found more economical to omit from their investment, substituting purchased power delivered to them by central-station power companies. The New Haven has purchased from The New York Edison Company all the power required for its western section of the alternating-current lines and terminals. The Pennsylvania Railroad has purchased from the Philadelphia Electric Company the power for the electrification of its main line from Philadelphia to Paoli and for its other contemplated extensions around Philadelphia. The London, Brighton and South Coast Railway Company buys current from the London Electric Supply Corporation, Ltd. The Chicago, Milwaukee and St. Paul Railway and the Butte, Anaconda and Pacific Railway buy power from the Montana Power Company.

Along every large railroad where the heavy traffic would warrant electrification there is, or can be made readily available, abundant supply of electrical power from power companies. These companies, by averaging the power demand from a great diversity of users, reap economical advantages in investment and in generation and distribution of power which the railroad cannot secure under independent generation. I wish to call attention to this phase of the problem, as the saving in investment in stations, substations and transmission lines may represent a sensible item in the investment of railroad electrification.

The central stations, besides offering investment and operating advantages, can furnish, in addition, a more reliable supply of power, because they command the best knowledge of the art of electricity supply, which is their exclusive and specialized business.

W. A. Del Mar (*New York City*).—This paper is interesting not only as a statement of operating results with the single-phase system of traction but also as a basis of comparison between steam and electric traction. Indeed, so nearly equal are the principal electric systems from an economic point of view that we may well afford to neglect their rivalry in view of the more vital rivalry between steam and electricity. I believe that the "battle of the systems" was largely caused by the advocates of each system being so carried away by enthusiasm as to be unable to tell the whole truth, whether in defending their own or criticising the others. Here, at last, we have a presentation of operating results, making it unnecessary to base conclusions upon specious arguments about details.

It is unfortunate that the operating costs are given for only two months of the year. The results would have been more valuable if they had been based upon a complete year, as it is almost impossible to select two really representative months, especially in view of inevitable variations of maintenance costs of equipment. The omission of the annual fixed charges is also to be regretted, as it is well known that the running charges can be made less with electric than with steam traction, but it is not always clear whether the fixed charges added by the electrical plant will destroy the favorable balance due to operating economies. Various cost data are presented, but in such form as not to be available for calculating fixed charges. We do not know, for example, whether the $15,000,000 expenditure mentioned by Mr. Murray includes the cost of reducing telephone disturbances and of altering the right-of-way to conform with electrical requirements.

One cannot help being appalled at development charges amounting to forty per cent. of the entire investment, as one would infer from Mr. Murray's statement that the present system could be replaced for sixty per cent. of the original investment. An interesting feature about the installation has been the development from the complex to the simple in mechanical details, and *vice versa* in the electrical features.

Examining the operating costs with the view of comparing them with steam operating results, one is confronted by a series of questions which, if unanswered, will render such comparison difficult. Having gone to great trouble to segregate and clearly present the operating costs, Mr. Murray proceeds to obtain unit costs by dividing these operating costs by car mileages and train mileages of unspecified nature. It is to be hoped that Mr. Murray will state the nature of the mileages with greater detail, particularly as to whether they include yard switching and light locomotives. These two items may easily amount to fifteen per cent. of the entire milieage.

The fixed charges given for the Cos Cob power station appear to be very low. It would be interesting to know whether they include depreciation.

An interesting feature of the New Haven installation is the use of meters on the locomotives. This enables an intelligent estimate to be made of the relative cost of different classes of service, such as passenger locomotive, freight, and multiple-unit. Meters on locomotives are not very accurate, due to vibration, but it is interesting to note that, provided the vibration is impartial with respect to making the meters read high or low, the probable error in the aggregate reading will be quite small, due to the large number of locomotives. Thus where there are 100 locomotives a possible error of twenty per cent. in each meter will cause a probable error of only $\frac{20}{\sqrt{100}} = 2$ per cent. in the total.

Electric railway men should feel very grateful to Mr. Murray for this paper, which will long be consulted as a classic upon a great engineering topic.

MR. R. H. WHEELER (*Assistant Electrical Engineer, Mackenzie, Mann & Co., Ltd.,* Montreal, Canada).—In this paper there comes a boon to those interested in the application of electricity to train movements in the practical definitions of conditions which affect the success of a railroad electrification, supplemented by copious data resulting from an extended period of operation. The haze from the "shots" of the "battle of systems" now clears away from the single-phase side of the field, showing an interesting array of results achieved.

Two points, from the many ably put forth, appeal to me for special emphasis. These are vital to the success and quantity of success, which latter is the chief "lure" of electrification.

First.—The careful analysis and choice of a form of electric power which may be standardized for all classes of train service on that road.

Second.—The "inheritance" to electric operation of "steam-trained" operators.

Under electric operation the power plant is separated from the locomotive, and it is evident that the economy of energy transmission, from its source to the wheels of the engine, is paramount. The overhead contact wire lends itself very readily to this transmission duty, in yards, terminals, on the road, and elsewhere. For reasons of high economy of transmission and diversity of transformations, Mr. Murray suggests that this wire be energized with 11,000 volts single-phase, 25-cycle power. By the use of the mercury-arc rectifier the admirable qualities of the series direct-current motor can be retained. This motor is especially desirable where the "density of traffic" factor is highest, as in suburban and terminal electrification, on account of its accelerating capabilities and weight economies, both in itself and its control. However, to carry about a rectifier upon the class of equipment employed in terminal service, even if rectified single-phase current were suitable, would impose a serious handicap in both weight and control complication. Rectified single-phase current is not ideal for direct-current motors of the usual design, requiring increased thermal capacity and thus weight. These reasons militate against the "standard" proposed as suitable for all classes of train service.

However, by placing the rectifier in the roadside substations and taking advantage of the economies and freedom of disturbance to other local circuits of a balanced three-phase, sixty-cycle supply, another "standard" results which supplies, over the overhead contact wire, power at 3000 volts direct current, and which has the desired essentials of transmission economy and standardization of motive power equipment. In the case of heavy grade divisions operated by rectifier substations, engines arranged for regeneration would be employed. This second "standard" is offered to emphasize Mr. Murray's definition of the successes arising from a choice of energy which can be standardized. A railroad which, in its initial electrification, utilizes a system which is capable of being extended through successive increases of electrically-operated territory has gone far to ensure successful electrification.

With the figures Mr. Murray presents, indicative of the successful operation of the New Haven motor cars and A. C.-D. C. engines since the last overhaul in a well-appointed maintenance shop, it is evident that the straight alternating-current engines will show greater economies. When the data are available from the Butte, Anaconda and Pacific Railroad, Chicago, Milwaukee and St. Paul Railroad, and Canadian Northern Railway giving results of operation, especially as the latter is to employ 2400-volt motor cars, another decisive step towards standardization can be made.

Secondly, I wish to emphasize the importance that "heredity" plays. Mr. Murray states that a thorough understanding must be had of the fundamental differences of steam and electric operation. Electric operation is a more exact science than steam operation, since a great many of the variable factors are removed. Chief of these, the power generating plant, is removed from the hands of the fireman, and he cannot now produce more power to get an overloaded engine over the road. Certain rules and axioms the officials of the operating department must appreciate in their adapting themselves to the era of electrification.

As well, the proper care and thorough inspection of electric equipment should be insisted upon and the long life resulting from renewals and not repairs be gained. It takes thorough investigation and time to care for such equipment, and in the early stages a little more lee-way should be given the shopmen. Coöperation in these things will produce the economies which make an electrification successful.

CLOSURE BY THE AUTHOR.

The writer takes this opportunity of expressing his appreciation of the many interesting points and suggestions that have been brought out in the discussion of the paper.

Before specifically commenting on the individual discussion, the writer desires to draw attention to an (apparent) error in the paper, which appears in Table 17, page 551 (May issue), under the statement covering the output of the Cos Cob Station. In that statement the fixed charges are named as 1.8 mills per k.w.h. This statement is based upon certain discounts allowed by the railroad company on installation charges, and also does not include depreciation. For outside comparative purposes, however, the rate of 1.8 mills should be changed to 2.9 mills, the latter figure being based upon an eleven per cent. rate on the total investment involved, carrying with it interest, insurance, depreciation, and taxes. The total cost, therefore, for current would become 8.01 mills per k.w.h. instead of the rate named in the paper of 6.91 mills, the former and larger figure being then in form as previously stated for comparative purposes.

I am indebted to Mr. H. P. Davis, vice-president of the Westinghouse Electric and Manufacturing Company, for his valuable discussion, and it is hardly necessary for me to point to the fact that not a little of the success in the application of high-tension alternating current to heavy traction systems is due to Mr. Davis. In particular are we indebted to Mr. Davis for the system of control that is used for electrical sectionalization, and, while the New Haven system now in service has been modified considerably to conform to the rearrangement of its circuits to reduce to a minimum electromagnetic induction, the earlier and basic elements which were worked out largely under the suggestion and coöperation of Mr. Davis are found in the system now controlling our entire lines.

Mr. Davis's long connection with the development of heavy electric railway equipment lends authority to his voice in commenting on the proper treatment which should be accorded electrical equipment. It might be said of electrical as compared to steam equipment, that *it is possible to get twice as much out of it and it is four times as different*, and the brains and fingers that are to handle the electrical equipment should have an electrical rather than steam instinct governing them, for the rapid progress and success of the application of electricity to heavy traction railways will largely depend upon the recognition of these simple facts.

Of the various departments of a railroad, covering respectively Executive, Traffic, Transportation, Legal, Operating, and Engineering matters, it were natural and seemingly logical to assign an electrification problem to its Engineering Department, and yet the advance of the art in the application of electricity for heavy traction purposes has been so rapid that I venture the opinion that ninety per cent. of the chief engineers of all the roads in this country, being so perfectly unacquainted with the underlying principles of the generation and application of electricity, would shrink from such a responsibility. It is to be noted that a few roads have placed their Engineering Department under the jurisdiction of their Operating Department, under which arrangement an assignment of the problem to the Engineering Department jeopardizes still further the desired result. The railway company will do well, therefore, when it decides to make so radical a change in its motive power, involving millions of dollars, to assign that responsibility solely to a man qualified to assume it, and also to see to it that his hands are not tied by having to report to officers in the Engineering and Operating Departments, who are unacquainted with the governing principles of electricity; indeed, on the contrary, it is my opinion that these departments should be requested by the president to coöperate to the full with the officer responsible for the work, thus clothing rather than robbing him of the authority so essentially necessary in producing an *electrical* plant to accomplish an *electrical* result.

As the above is true in the matter of electrical engineering and construction, it is to a very great extent true in the matter of operation, and, as pointed out in the paper, while no radical change is necessary in the general railroad organization of to-day, I cannot too greatly emphasize the absolute truth that when a railroad company has adopted electricity to be its motive power the operating officials should state the *schedules* and *consist* of trains, and then abide by the decision of the electrical officer (whose duties might be defined as " in charge of electrical engineering and construction and the features of electrical operation ") as to what power, both generative and motive, is necessary.

In the past there has been an appalling attitude on the part of officials of some steam railroads electrifying—rather than welcoming the selection of electrically-trained men for positions such as superintendents of electrical shops, road foremen of electric engines, master mechanics for electric engines, to insist that these positions be filled by men who have occupied seemingly analogous positions under steam locomotive conditions, notwithstanding their past environment, experience, and adaptability to the new and different conditions confronting them make them unfit, both from a safety and economic standpoint, to serve. Railway managements are now waking up to these facts, and in the last year great improvement in the electrical *personnel* of the operating departments has resulted. There is much along these lines to be accomplished yet, and dire necessity has as much as anything brought about the real and final awakening of a differentiation between electrical talents that apply and those of steam that do not. This information is too vital, and, indeed, as it constitutes the very rivets and gusset plates of the electrification bridge over which we are crossing to more economic, safe, and satisfactory railroading, it has a fitting place here. It has been a strenuous past; the bills have all been paid, and as sure as they represent the millions of dollars lost in the past, so do they equally represent the millions of dollars to be saved in the future, and so at least we can say it has taught us "how not to do it."

Referring to Mr. McHenry's comments: It has always seemed to me that electrification has been an advantage to "the many" at the expense of "the few." While it is true that electrification for *economy's* sake bids fair to preëmpt the use of it for *necessity's* sake, still it is fair to believe that the consideration of electrification of city terminals carries for the present a more popular justification, and if it can be proved beyond doubt that the electrification of city terminals imposes a financial burden upon the railroad, it would seem to me that Mr. McHenry's suggestion of an "outside" tax should find justification.

In Mr. George R. Henderson's valuable contribution to the paper an excellent point is made with regard to the uniformity of traffic being a most important adjunct in securing the economies of electrification. In nearly all the situations of electric power generation and distribution we seldom, if ever, hear of one wherein a one hundred per cent. load factor obtains. There are thus certain hours in a day, and in railroad work generally two (if only the passenger service is operated by electricity), when the power requirements are at a maximum. It is thus seen that at all other times of the day and night full advantage is not being taken of the total electrical investment. Realization upon Mr. Henderson's suggestion is to a large measure accomplished by the electrical movement of freight as well as passenger, as the maximum power demand for the former can be made to follow at the time of minimum demand for the latter. Those who have studied the matter of load factors in their application to lighting and street railway properties have accustomed themselves to such figures as from thirty-five per cent. to forty-five per cent. and sometimes reaching fifty per cent. load factor. I have no doubt it will be of interest to state that in plotting the combined load curves of the New Haven passenger, freight, and switching services without any rearrangement of the schedules as they are made up to-day a load factor of seventy-five per cent, is secured, which figure, I am sure Mr. Henderson will agree, bespeaks the uniformity of the density of traffic at least in the New Haven case. It is apparent, therefore, that in the study of electrification equal consideration should be given to both freight and passenger movement.

With regard to fuel saving, if the economy of generating units remained fixed, it would be fair to grant Mr. Henderson's point with regard to the change of ratio from fifty per cent. to sixty-five per cent. On the other hand, the thermal efficiency of generating plants is easily keeping pace with that of steam locomotives, and, granting this, there are no other constants or variables which will tend to alter the ratio of one or two in favor of the fuel economy of drawbar pull by central electrical stations *versus* steam locomotives.

Mr. Henderson's point with regard to the transfer of steam locomotive power to different divisions of a road where congestion may require is interesting; I can conceive, however, of a division electrifying, with economy, not inclusive of the financial credits due to the steam locomotives replaced, thus automatically providing steam locomotives for service in the congested districts. The principal value of Mr. Henderson's observation on this matter to me is in pointing out that every electrification is a study in itself, and in electrifying one division its effect may be felt in many different ways in other divisions.

I am indebted to Mr. F. E. Wynne for his unit analysis of investment cost. I think that he has transformed electrification investment into a very unique and interesting basis for consideration. His assumption with regard to the limitation of passenger locomotive and multiple-unit car mileages is entirely correct; the morning and afternoon suburban traffic to and from New York City, with its close headway, makes the problem of securing high car and locomotive mileage most difficult.

Answering Mr. Wynne's question as to the statement of increased reliability of operating when electric was substituted for steam service, I would advise that this was, as he surmised, upon a failure basis. A fair average for steam locomotive operation might be cited as 5000 miles per engine failure, whereas electrical operation certainly should be 12,000, and in a number of instances on the New Haven it has been as high as 18,000, and it is my understanding that both the Pennsylvania Road and the New York Central Road have reached figures higher than this, our own mileage having been lower than the others, due chiefly, I think, to the requirement of the dual A. C.–D. C. operation.

I am entirely in agreement with Mr. Wynne that the maintenance and repairs on electric locomotives should be compared to those of steam upon the basis of equal service and weight on drivers.

Again I find comfort in Mr. Wynne's emphasis of the highest importance to securing the proper electrical administrative forces in the electrified zones of steam railroads.

Answering Mr. Wynne's inquiry with regard to Table No. 17, as explained in my general note forward to this discussion, no allowance was made for depreciation under fixed charges.

Mr. Philip Torchio's contribution is of great interest, and shows the trend and possibilities of large central-station power in the field of electrification. The introduction of an alien power to produce drawbar pull upon a railroad is certainly a departure from past practice. The acceptance of this practice hyphenates the name of the mechanical superintendent, and the central power stations who have relieved him of a part of his duties will do well to see that this new step is justified, and it can only be justified by a practically perfect continuity of service.

Many railroads electrifying will insist upon the internal control of their entire power, others will mingle purchased power with their own power, and, finally, still others will depend entirely upon purchased power. I see no particular difficulty arising in any one of these three arrangements of supply, and I have agreed with Mr. Torchio that the only true basis for a contract by a railroad for the supply of outside power will be that that power can be supplied with as equal reliability as the power could be produced by the railroad company and at equal cost.

The higher thermàl efficiency secured in the use of large generating units affords an opportunity for large central-station plants to sell power to railroads, a measure of the justifiable profit in this sale being in the difference in efficiency between the smaller generating station (required by the railroad) and that of the central station. Such an arrangement as Mr. Torchio has pointed out provides an economical supply of power, and at the same time obviates the necessity of the railroad company investing in this feature required for electrification. Indeed, and digressing for a moment, I will go a step further under Mr. Torchio's thought and say that in these days when railroads are so hard up for cash the " Equipment Trust " offers a relief in the matter of the purchase of electric motive-power equipment, leaving as the only cash investment necessary on the part of the road electrifying that incident to the cost of the distribution and contact system required for the operation of its trains, and such buildings or modifications of buildings as will cover the shopping requirements of the new electrical equipment.

Commenting on Mr. Alfred W. Gibbs's valuable contribution in the discussion: His first point is well taken, and has been long recognized as one of the serious capital and operating expenditures where the problem of electrification is applied to deviating lines entering a city, and unless, as Mr. Gibbs points out, each one of these lines is electrified throughout the entire division, it is necessary to arrange local terminals to permit a change from steam to electrical operation. Such a condition, for example, is manifest in the study of the electrification of the various lines of the New York, New Haven and Hartford, the Boston and Albany, and the Boston and Maine Railroads entering the city of

Boston. As Mr. Gibbs advises, this is quite properly a charge to electrification, and a heavy one. On the other hand, large cities gridironed with their entering roads may have a density upon these tracks which will permit the terminal charges and still be within the economic limit of electrification. The tendency will be, of course, to electrify roads entering the cities upon which the greatest traffic obtains, and those having a lesser density will in turn be electrified as increased density justifies. The difficult financial situations in which the railroads of to-day find themselves are becoming better appreciated daily by the public, and it is safe to assume that, as density of traffic is the controlling factor in electrification, a city's people will see the justice of such a proposed procedure.

I fear my remark with regard to the third rail " having gone to seed " has been given more weight by Mr. Gibbs than was intended. Let me hasten, therefore, to withdraw any seeming attitude of criticism on my part with regard to the engineers responsible for the introduction of the direct-current system, particularly in the New York City terminals. But I confess that the adoption of the overhead system by the Pennsylvania Railroad Company for its Philadelphia electrification offered partial grounds for the suggestion that the third rail was past its flowering stage.

Mr. Gibbs's table showing the economy of steam locomotives with more liberal boiler capacity and with superheat is most interesting. The note that Mr. Gibbs adds, however, that *" These are the rates when running, added to which are certain standby losses at terminals,"* transforms " test " into practical conditions, and, as explained in my commentaries on Mr. Henderson's discussion, the improvement in thermal efficiency of central power stations can easily keep pace with any similar improvements in the steam locomotives. I feel sure that Mr. Gibbs will later find that my statement with regard to this matter is correct, and, if he does so, will take the first opportunity to withdraw his criticisms of my statement that " one pound of coal burned under the boiler of a central power plant will develop twice the drawbar power that the same amount of coal will produce when burned in a locomotive firebox." When I made the statement I had, of course, reference to the average conditions of practical operation.

As explained in the paragraph forward to my commentary on the general discussion, the figures for depreciation upon the Cos Cob power station were not included, and for comparative purposes they should have been allowed. Mr. Gibbs has named a rate of 0.35 cent or 4 cents per k.w.h. as the amount that should apply, and it is to be noted that upon the basis of eleven per cent. upon the total investment made, covering interest, insurance, depreciation and taxes, the figure 0.29 cent, while less, does not differ greatly from that suggested by Mr. Gibbs.

Mr. Wheeler discusses most interestingly two vitally important points on the matter of electrification:

(1) The form of electric power which may be standardized for all classes of train service.

(2) The inheritance in the electric zone of "steam-trained" operators.

With regard to (1), the question of the location of the rectifier on or off the locomotive will always admit of local analysis for the most economic result. Mr. Wheeler has pointed out some very interesting possibilities in this direction.

With regard to (2), the matter of electrical administration, I have already expressed myself at such length on this matter that it will be only necessary to acknowldge with interest Mr. Wheeler's concordant sentiments.

Mr. W. A. Del Mar has asked some very pertinent and interesting questions, which I am very glad to answer. With regard to the expenditures made to reduce telephone disturbances, and of altering the right of way to conform with electrical requirements, these were included in the general figure of $15,000,000 mentioned in the paper. It is of interest, however, to note that past experience has indicated a proper method of laying out the transmission and distribution system whereby automatic compensation for telegraph and telephone disturbances can be secured for a very nominal amount. For example, in the case of the electrification of the four-track lines between Stamford and New Haven, the arrangement of transmission and distribution for the most economic traction result proves the most efficacious for reduction of the telegraph and telephone disturbances.

It is of interest to note that Mr. Del Mar is appalled at the development charges of the single-phase system, and, while I am at a loss to understand how a "fact" can be presented in an "ingenious way," as an example of a reduction of costs, our strain insulators in 1907, when we first began the electrification, cost $63. To-day, with factors of safety three times both the electrical and mechanical values they had in their original installation, the cost has been reduced to $7. A longer experience in the handling of work-train service and the administration of construction work upon those work trains are points along the curve representing forty per cent. in the reduction of construction, etc.

With regard to the four questions Mr. Del Mar has asked, I am glad to answer them as follows:

(1) *Q.* Do these mileages include or exclude yard switching?

A. The mileages given for both passenger and freight service do not include yard switching (*yard switching* is taken care of by yard switchers designed especially for that purpose).

I would advise, however, that the locomotive miles as shown on line 2 of the operating statistics, in both the case of the passenger and freight service, include the mileage of locomotives in trains and also the miles " run light " between engine-houses and stations. In figuring the passenger operating costs, however, the mileages of engines "run light" between stations are also included, thus giving the total passenger locomotive miles, and in figuring the operating costs on freight locomotives likewise the miles of light moves and the mileage of locomotives switching at way stations on the main line are also included. It would doubtless be of interest to Mr. Del Mar to know that we have added a third sheet of statistical information having reference only to yard switching mileage and yard switching costs, which sheet had not been inaugurated at the time the paper was written.

(2) *Q.* If they exclude yard switching, do not the operating costs appear unduly high? If they include yard switching, how is it estimated?

A. The above answer to Question 1 doubtless serves as an answer to Mr. Del Mar's second question. While agreeing to his statement that the costs are high, I only hope that I have made the reason for this clear, especially in view of the typical record of the costs of maintaining the ten engines which at the time of the paper had received a full overhaul in the new shops. As previously explained, some of these engines had run 300,000 miles without undergoing any general repairs.

(3) *Q.* Are light locomotive mileages included in train miles?

A. The train miles did not include the mileage of locomotives "run light," but have been recorded and are included in the total locomotive mileage in computing the unit cost per locomotive mile both in freight and passenger service.

(4) *Q*. The fixed charges given for Cos Cob power station appear to be very low. It would be interesting to know whether they include depreciation.

A. As explained in the previous part of this discussion, they did not include depreciation.

Mr. Del Mar's point with regard to the negligible error of meter registration on locomotives is very interesting, and, so far as we have been able to determine, the meters have been an accurate and valuable adjunct in the determination of the general distribution of power.

The Fire Hazard in Turbo-Generators. G. S. LAWLER. (*National Fire Protective Association,* vol. 8, No. 4.)—The chances of electrical generators of the older types being seriously injured by fire in the event of some part of the insulation failing are slight. Their freedom from fire damage is due principally to the comparatively low speeds, the accessibility of the combustible insulation, and the large mass of the machines per unit of capacity. In the case of generators of the turbo type this condition is reversed. Undoubtedly manufacturing companies have given the subject serious thought and have employed all means practical at the present time to reduce the fire hazard to a minimum, but there is still very much to be desired. Besides improving the non-combustible properties of the coverings, it would seem feasible to provide means for cutting off the ventilating system and thus diminish the supply of oxygen, or even to introduce carbon dioxide in the place of air in the cooling system.

The Theory of Cold Light. W. D. BANCROFT. (*Transactions of the Illuminating Engineering Society,* vol. x, No. 4.)—It is claimed that all chemical reactions tend to emit light, and that they all emit light if made to take place very rapidly. It is shown that the luminescence of salts flames is a chemiluminescence, and the method of determining the reaction is outlined for the specific case of cupric chloride. If a suitable chemical reaction can be made to take place sufficiently rapidly without any marked evolution of heat, cold light is obtained. The firefly has solved this problem, though the nature of the substance which oxidizes is not known. The chemist will some day solve it in another way. The Moore light is probably a case of chemiluminescence, but most commercial forms of lighting depend on temperature radiation for their efficiency.

The Estimation of High Temperatures by the Method of Color Identity. C. C. PATERSON and B. P. DUDDING. (*Proceedings of the Physical Society of London,* vol. xxvii, part iii.)—(1) Preliminary experiments are described on the method of "color identity" adapted to the estimation of the temperature of incandescent substances, such as metal or carbon radiating in the open; by this method the "true" temperature of certain bodies as distinct from their "black body" temperatures can be arrived at with a very fair degree of accuracy. (2) By the color identity method the total luminous radiation (white light) from a black body is made identical in color with that from the incandescent metal under examination by adjusting the black body until there is color identity in the field of a Lummer-Brodhun photometer. (3) Comparisons are made with the results so obtained with those obtained by other methods, and the color identity method is shown to give the correct result for melting platinum. (4) Formulas are deduced, based on the fundamental theories of energy radiation and the sensitivity of the eye, connecting the temperature of carbon and tungsten filaments with their lumens per watt, and it is shown that these expressions hold from the lowest to the highest values of lumens per watt. (5) It is shown that the color identity method of determining filament temperatures is practically independent of the cooling at the ends of the filaments of ordinary lamps. (6) An explanation is given of the principal factors and limitations of the color identity method, in which it is shown that accurate results should be obtained so long as the bodies under consideration act as "gray" bodies throughout the visible spectrum, and that there will be a tendency to error to the extent that they depart from the gray body condition in the *visible spectrum.* (7) The color of the radiation from melting platinum is shown to be the same as that from a carbon filament lamp operating at 2.65 lumens per watt or 4.75 watts per mean spherical candle or, approximately, 3.8 watts per mean horizontal candle.

Largest Commercial Gasoline Engine Ever Built. ANON. (*Scientific American,* vol. cxii, No. 24, 588.)—What is said to be the largest gasoline engine ever built has been installed in a double-ended ferryboat utilized for the transportation of trains across an arm of San Francisco Bay. Although designed for marine work, it shows to a remarkable degree the influence of automobile practice in its general appearance. Weighing approximately 120,000 pounds, this 600-horse-power unit is the climax of a gradual development of the heavy gasoline engine on the Pacific coast. It has four cylinders of 16-inch bore, each measuring nearly six feet and weighing 1700 pounds. The normal speed of the engine is 225 revolutions per minute. The trips are not long, and between runs all fuel consumption ceases, effecting a considerable saving over steam despite the high cost of fuel for operating an engine of this size.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

A STUDY OF THE QUALITY OF PLATINUM WARE.†

By George K. Burgess and P. D. Sale.

[ABSTRACT.]

THERE has been devised a simple, thermo-electric method suitable for the determination of the purity of platinum ware. This method does not mar the article tested, and gives data for the classification of platinum in terms of its equivalent iridium (or rhodium) content.

There were examined by the thermo-electric method 164 pieces of platinum ware, of which 26 per cent. contained less than 0.5 per cent. iridium and 67 per cent. less than 2 per cent. of iridium. Of 84 crucibles, 36 per cent. contained less than 0.5 per cent. iridium and 87 per cent. less than 2 per cent. iridium.

A method has been developed for determination of the exact loss on heating of platinum crucibles by means of a suitable electric furnace containing no heated metal parts.

Fourteen crucibles of various makes and grades were examined for loss in weight on heating and after acid treatment following each heating. Their magnetic susceptibilities were also determined. The susceptibility of pure platinum is zero, and the range of susceptibility of seven crucibles is 1 to 125.

The heating losses per 100 cm.^{2} of practically iron-free crucible surface at 1200° C. ranged from 0.71 mg. to 2.69 mg. per hour, the lesser losses being for crucibles containing rhodium and the greater losses being associated with iridium.

Iron appears to lessen somewhat the loss of weight on heating, but its presence is objectionable on account of the soluble oxide formed on the crucible surface. The chemical analysis and magnetic measurements place the crucibles in only approximately the same order as to iron content; the magnetic susceptibility is not, however, proportional to the iron content.

---

* Communicated by the Bureau.

† To appear as a Scientific Paper of the Bureau of Standards.

It appears to be possible, from thermo-electric and microscopic examinations of a crucible, to predict its probable loss of weight on heating within limits close enough for analytical purposes.

Suggestions are offered concerning the specifications of highest grade platinum crucibles, including the substitution of rhodium to 5 per cent. for iridium, and the practical elimination of iron.

Whether crucibles have been long in use or not, after the first two or three heatings and acid washings, appears to make little or no difference on their behavior as to losses on heating and washing.

The nature of the process of disintegration of platinum and its alloys is briefly discussed.

A DIRECT-READING DEVICE FOR USE IN COMPUTING CHARACTERISTICS OF VACUUM TUNGSTEN LAMPS.

By J. F. Skogland.

[ABSTRACT.]

IT has been shown in a previous paper * that the ordinary characteristic relations of vacuum tungsten lamps may be expressed with high precision by a set of characteristic equations, each involving two variables; or solutions may be made more quickly by employing tables computed from the equations. For example, having given observed values of voltage, candle-power, and watts per candle, the values of candle-power and watts per candle at any other voltage are obtained from the equations or tables as follows:

1. From the observed values of voltage and candle-power their normal values,—that is, their values at normal watts per candle (1.20),—are computed.

2. The ratio of the desired voltage to the normal voltage just found is computed.

3. Substitution of this voltage ratio in the proper equations, or reference to the corresponding point in the tables, gives a candle-power factor and the actual watts per candle.

---

* Middlekauff and Skogland, "Characteristic Equations of Tungsten Filament Lamps and Their Application in Heterochromatic Photometry," Bulletin of the Bureau 11, p. 483 (1914); Scientific Paper No. 238.

4. The normal candle-power is multiplied by the candle-power factor to obtain the desired candle-power.

This process, though simple, requires considerable time before a solution is obtained. The direct reading device here described and presented ready for use solves directly and without preliminary reduction all problems introducing as variables the voltage, candle-power, and watts per candle of vacuum tungsten lamps. Its construction depends directly upon the characteristic equations mentioned above.

This device consists of volt, watts per candle, and per cent. candle-power scales. The watts per candle and per cent. candle-power scales are fixed in their relation to each other. The volt scale is arranged to be detached from the plate, so that it may be applied to the fixed scales at the point corresponding to observed values of watts per candle and voltage.

From a single setting of the volt scale to observed values within the range of from 0.70 to 2.05 watts per candle may be read values of any one of the variables at any other point within this range. The volt scale has a range of from 94 to 166 volts. The chosen limits of watts per candle and voltage are considered sufficient to include settings and solutions for 105- to 130-volt lamps in standardizing and life test-work.

A test of the device, illustrated in part by examples, indicates that, on an average, values of per cent. candle-power and of watts per candle read therefrom deviate from those obtained by use of Tables 20 and 22 of the paper just referred to by amounts not exceeding 0.10 per cent. and 0.05 per cent. respectively; also that values read from the scales check observed values very nearly as closely as those computed by use of the tables.

All of the points (referred to horizontal and vertical scales of equal parts) through which lines of the scales of this device were drawn have been tabulated, so that similar scales of the same or different range may be constructed directly from these values. Sufficient discussion of the derivation of these values and of the relative position of the scales has been given to direct the construction of scales not included within the watts per candle range here employed. By the general method of this paper any related functions of exponential form and of the same degree as the characteristic equations may be represented and used as scales of a similar device.

The chief merits of the device when compared with other methods of characteristic evaluation seem to be its simplicity, precision, and saving of time resulting from its use. Solutions are made directly, without reference to normal watts per candle, voltage ratios, exponents, etc. These considerations should recommend it to testing and standardizing laboratories.

CONSTRUCTION OF PRIMARY MERCURIAL RESISTANCE STANDARDS.

By F. A. Wolff, M. P. Shoemaker, and C. A. Briggs.

[ABSTRACT.]

The paper deals with the construction of four one-ohm mercury standards of resistance in accordance with specifications adopted by the International Conference on Electrical Units and Standards (London, 1908).

The London Conference defined the international ohm as the resistance offered to an unvarying electric current by a column of mercury at the temperature of melting ice, 14.4521 grammes in mass, of a constant cross-sectional area and of a length of 106.300 centimetres.

Owing to the impossibility of exact realization of the above conditions, principally because of the impracticability of securing glass tubing of strictly uniform bore, certain specifications were essential. Those adopted specified that the tubes used must be made of a glass the dimensions of which change little with time; that they be well annealed and straight; that the bore be as nearly as possible uniform and circular; that the area of cross-section of the bore be approximately one square millimetre, and that the mercury have a resistance of approximately one ohm.

It was also specified that each tube be accurately calibrated, and that no tube have a calibre correction greater than 5 parts in 10,000. The length of the tube, the mass of mercury the tube contains, and the electrical resistance of the mercury must all be determined at a temperature as near to 0° C. as possible, all measurements being corrected to 0° C.

The four tubes used at the Bureau were selected from a large number of tubes of Jena 59 III glass, specially drawn by Schott

and Genossan, and were straightened, annealed, and graduated by M. Dandin in Paris.

At the Bureau of Standards they were very carefully calibrated, their calibre factors, ranging from 1.000047 to 1.000096, being determined to an accuracy of about one part in a million.

The tubes were cut at points giving a resistance, including the end correction, of approximately one ohm, the cuts being located at points for which the cross-section could be most accurately calculated. The ends were ground and plane polished. The tubes were tapered at the ends to fit into the end bulbs, used in making electrical measurements, and the glass cleaning and drying fittings.

The Reichsanstalt method was employed for the determination of Mo, the mass of mercury required to just fill a tube at 0° C. A tube was exhausted, filled with mercury and placed vertically within a double-walled ice-bath, the lower end of the tube being sealed by a plane polished plate and the upper end, carrying a slight excess of mercury, being protected by a ground glass cap.

The excess of mercury was removed by stroking off with a plane polished glass plate in a gimbal mounting, the condensation of moisture being eliminated by a current of cooled and dried air directed at the end of the tube and at the stroking-off plate. Weighings were made in a special balance room, on a Stückrath balance sensitive to a hundredth of a milligramme. Six fillings of each tube were made, the mean of the average deviations of the individual fillings from their respective means being but ± 4 parts per million.

The problem of determining L_0, the length of the axis of a tube at 0° C., was reduced, through the use of suitably-ruled end pieces of platinum-iridium, from one of comparing end standards to that of comparing line standards. Comparisons were made directly with corresponding known intervals on a nickel-steel meter. The length constant added, due to the end pieces, was determined by abutting the end clips and measuring the interval between the lines on them by comparison with a subdivided decimetre standard. The probable error in the lengths as determined, all things considered, did not exceed five ten-thousandths of a millimetre.

Electrical comparisons of the mercury units were made by the Thomson bridge method, the mercury units and five sealed manganin standards being substituted in turn in the same bridge arm.

The ratio coils and the manganin standards were contained in a thermostatically controlled oil-bath, while the mercury units were in the ice-bath adjoining. Connections from the tubes to the bridge were made by inserting heavy copper conductors in the glass terminal protecting tubes of the end bulbs employed, the tubes being partly filled with mercury.

Seven fillings of each tube for electrical comparison were made in 1911. The international ohm as defined by the four mercury standards was found to be 25.5 millionth smaller than the international ohm as represented by the manganin coils at that time. The average deviation of the four tubes from their mean was but ± 5 parts per million.

A second and third series of electrical comparisons, made in June and December, 1912, showed the mercury standards to have changed with respect to the wire standards. Redeterminations of Mo, L_0, and the calculated R_0 were therefore made for each tube, the average change found being 1.1, 9.4, and 8.2 parts per million respectively.

On the basis of the above new determinations the international ohm, as represented by the four mercury standards in December, 1912, was 12.5 millionths smaller than the international ohm as represented by the manganin coils at the same time.

England, Germany, Japan, Russia, France, and the United States now have mercury standards of resistance. Comparison of the units defined by the mercury standards of the above countries in 1913 (those of France excepted, dates not being available) indicate a very satisfactory agreement, the average deviation of the units of the several countries from the mean being about ± 7 parts per million.

THE FRANKLIN INSTITUTE

AWARD OF THE FRANKLIN MEDAL.

At a stated meeting of the Institute, held on the evening of Wednesday, May 19, 1915, Dr. Walton Clark, President of the Institute, presiding, the Institute's Franklin Medal was awarded to:

> HEIKE KAMERLINGH ONNES, of Leiden, Holland, in recognition of his "long-continued and indefatigable labors in low-temperature research, which have enriched physical science not only with a great number of new methods and ingenious devices, but also with achievements and discoveries of the first magnitude."
>
> THOMAS ALVA EDISON, of Orange, N. J., in recognition of the value of "numerous basic inventions and discoveries forming the foundation of world-wide industries, signally contributing to the well-being, comfort, and pleasure of the human race."

The work of Professor Onnes and Mr. Edison was described by Dr. Harry F. Keller, and Dr. George A. Hoadley followed by a statement relating to the founding of the Franklin Medal.

At the conclusion of the regular business of the meeting the president of the Institute, Dr. Walton Clark, said:

The Chair now recognizes Dr. Keller to introduce the medallists upon whom, on the recommendation of the Committee on Science and the Arts, have been conferred the Franklin Medal, generously founded by Mr. Samuel Insull and nobly designed by Dr. R. Tait McKenzie.

Dr. Keller: Mr. President, our gathering here to-night in this venerable hall is an occasion of peculiar gratification and of rejoicing to the members of The Franklin Institute. It is not the recurrence of a time-honored custom, but an event which is to initiate a new series of annual functions of this Institute, made possible by the munificence of one of its distinguished members.

Your presentation, Mr. President, of the two first impressions of the Franklin Medal marks the inauguration of what we hope will every year stand out as a red-letter day in our calendar, the crowning of supreme achievement in science by the award of a medal of such artistic merit and intrinsic value as to render it a fitting tribute to the recipient.

The donor of the fund which enables The Franklin Institute to confer such an award upon scientific discoverers and inventors is Mr. Samuel Insull. He is the president of a corporation which owes its inception and its marvellous success in a large measure to scientific labor and inventive genius, to discoveries and their practical applications which have been made, not by one man, or a few men of our country, only, but by a host of workers whose lives and activities had their scene in every part of the civilized world. With these facts in mind, Mr. Insull has wisely and fittingly defined as the scope of the new award the recognition of highest achievements in the fields of pure and applied science, without regard to the nationality of the scientist.

As in the case of the other awards made by the Institute, the naming of the Franklin Medallists has been entrusted to the Committee on Science and the Arts, and, in accordance with its custom, this committee has delegated that responsible and pleasant duty to a sub-committee of which I have had the honor to be chairman.

Impressed with the importance of recommending for the initial awards names that might stand as precedents for the coming years, the sub-committee decided upon a course which, it is hoped, will meet with the approbation of both the Institute and the public. In order to emphasize the broad scope as well as the international character of the award, it was agreed that of the two names chosen one should be that of a scientific investigator and the other a representative of applied science; also that one of the medallists should be an American and the other a foreigner. In view of conditions resulting from the war which is raging in Europe, it was deemed advisable that, other things being equal, the foreign medallist should be a citizen of a neutral country.

The two names which were the unanimous choice of the sub-committee, and which had also the unanimous approval of the Committee on Science and the Arts, meet these conditions in every respect. It may be doubted whether the selection would have been different even if it had been made without any restrictions.

The question as to which of the two awards should go to the American and which to the foreigner did not seem difficult to decide, for, while it is true that our country is now contributing its full share, and even more than that, to the advancement of science, it is universally conceded that in the practical application of scientific principles the American people are preëminent. If our country can claim to be "the land of unlimited possibilities," this phrase may certainly be applied also to the inventive power and the engineering skill of her sons. It was natural, therefore, to think of an American in connection with the award in applied science.

The scientist we desire to honor for the truly wonderful achievements he has made in experimental physics is a native of Holland, and professor in the University of Leiden. Heike Kamerlingh Onnes was little known, even among men of science, until a few years ago, when he announced the liquefaction of helium at a temperature but a few degrees above absolute zero. The award of the Nobel Prize for Physics in 1913 first directed popular attention and curiosity to the work of this scientist, and to that unique workshop of his in the Leiden University, the cryogenic laboratory. Attention was then called to the fact that the production of extreme low temperatures and the liquefaction of helium by Professor Onnes were by no means the fruits of what might be called *tour de force,* but the culmination of long-continued, comprehensive researches, involving profound knowledge, inventive power, experimental skill, and ability of a high order to organize and direct. This work in molecular thermodynamics derived its inspiration from van der Waals's epoch-making investigations on the critical states, and practically began in the year 1882, when the two most distinguished physicists which Holland has produced, H. A. Lorentz and H. Kamerlingh Onnes, were appointed to the chairs in physics in the University of Leiden.

The coöperation of the two men soon made Leiden a centre of physical research. As is well known, the achievements of Lorentz lie mainly in theoretical and mathematical physics, but Onnes at first directed his attention to the equipment and development of the laboratory. *"Door meten tot weten"* ("knowledge rests upon measurements") he inscribed above its entrance. His great ambition was the creation of a laboratory devoted to low-temperature research. To attain this object he abandoned for many years the researches on which he had been engaged, and devoted his time to the construction of apparatus for the liquefaction of gases and the measurement of low temperatures. As a part of his plan he attached to the laboratory a training school for instrument makers, in which instruction was also given in the handling of apparatus. It was thus that he secured the staff of trained assistants which he required for his experimental work.

During the ten years he spent on constructing the cryogenic laboratory he also directed numerous important researches on electro-optical and magneto-optical subjects. In this work he enjoyed the constant coöperation of Professor Lorentz, who doubtless suggested many of the problems. Among the results was the great discovery known as the Zeeman effect.

After the completion of the liquid-oxygen equipment of his laboratory, Onnes decided to devote his entire time and attention to low-temperature research. Since 1900 the *Leiden Communications,* the official publication of the laboratory, presents a record of the rich harvest of results and discoveries he secured in the cryogenic laboratory. He attempted the liquefaction of hydrogen, but in this and in the solidification of hydrogen Professor Dewar, of London, his great rival, stole a march on him. Onnes, however, immediately took advantage of the new range of low temperatures by extending his equipment so as to permit the investigation of phenomena to temperatures as low as −259° C. In experimenting with a mixture of hydrogen and helium he made the remarkable observation that at the temperature of liquid hydrogen helium can be so compressed that the gas actually sinks to the bottom of the liquid.

After innumerable preliminary trials he finally succeeded, on July 10, 1908, in liquefying helium, an achievement which is one of the greatest triumphs of experimental skill and of ingenious combination of every conceivable resource. The temperature at which liquefaction took place was −269°, and by allowing the liquid to boil under reduced pressure a temperature but one degree above absolute zero was reached. Time does not permit me to dwell on the great number of new and important results that have been obtained by Onnes himself, as well as by other physicists working in his laboratory, with the aid of liquid helium. In conclusion I would only mention an almost incredible, yet fully substantiated, observation of Professor Onnes; namely, the fact that at temperatures but a few degrees above absolute zero the resistance of metals such as mercury, lead, and tin falls to practically *nil,* so that an electric current will continue to flow almost undiminished after the magnet that has induced the current has been removed from the coil.

Mr. President, I now have the honor to present to you His Excellency, Chevalier W. L. F. C. van Rappard, who on behalf of the Royal Netherlands Government will accept from you the Franklin Medal for Professor Onnes.

PRESIDENT CLARK: Your Excellency, The Franklin Institute, acting under a recommendation of its Committee on Science and the Arts, has awarded its highest honor—the Franklin Medal and Diploma—to your distinguished countryman, Professor Onnes, for his signal services to humanity, rendered in the field of science.

Pursuant to your kind consent I now have the privilege of presenting this Medal and Diploma to you, to be transmitted to Professor Onnes, through the State Department of your gracious Sovereign. The Franklin Institute is appreciative of the distinction conferred upon it by the participation of Her Majesty's Government in this ceremony.

CHEVALIER VAN RAPPARD (On behalf of the Royal Netherlands Government, for Prof. Heike Kamerlingh Onnes): Mr. President of The Franklin Institute of the State of Pennsylvania and Members of The Franklin Institute: I consider it a great honor and a most agreeable duty to accept at your hands the Franklin Medal, founded by Mr. Samuel Insull, for the recognition of those workers in physical science, without regard to country, whose efforts, in the opinion of the Institute, have done most to advance the knowledge of physical science and its applications. I feel sure that that most distinguished countryman of mine whom you have honored so highly by awarding him the Franklin Medal, if he could be here to-night, to receive himself this high token of your recognition of his abilities and of his labors, would be able to express more eloquently than I am able to do his deep gratitude for the great honor that has been bestowed upon him, and, moreover, he would have found words to express his admiration of your Franklin Institute, and of its influence in the realms of mechanical science and the arts. Therefore, I feel that in this gathering of learned men I am a poor substitute for a man such as Professor Onnes. However, it is perhaps an advantage that he is not here, but that the official representative of the Netherlands now stands before you to receive this great honor that has been bestowed upon one of the Netherlands' most illustrious citizens, because that citizen, illustrious as he may be, is also a modest man, and if he had been here, he probably would have spoken to you only of his personal feeling of gratitude and thankfulness of what you think of him and of your high opinion of his knowledge, but I can do more, I can say that it is not only Professor Onnes who has been honored and is thankful for the great honor that has been given to him, but that also my whole country feels very honored and happy on account of the rare distinction that has been visited on one of its sons. We are proud of Professor Onnes, we know that he is one of the famous men that the old University of Leiden has given not only to Holland, but also to the whole world. It is useless to cite names, you all know them as well as I do. You know that among the famous men Professor Onnes takes a most prominent place, but from to-day we will think more of him and we will rank him higher because that modest worker at the other side of the water has been able to attract upon himself the attention of The Franklin Institute of the State of Pennsylvania.

You know I am a layman. I had heard of the scope of The Franklin

Institute—and every civilized man may feel interested in an Institute bearing the name of Benjamin Franklin—but, Mr. President, you were kind enough to send me some literature and information relating to the Institute and its activities, which documents I have read with the keenest interest, and the more I read, the more I realized how proud Professor Onnes and the Netherlands must be when the Franklin Medal reaches our shores. It will always be a valuable gem fixed to the scientific crown of our oldest university, the University of Leiden, and it will always be a proof that the Netherlands strives to be great in those things in which also a small country can be great. It is therefore my very agreeable task to accept this medal. And let me say that Holland has always considered the United States of America as its big younger brother. The old Dutch settlers came over to your country many years ago, and brought to you those principles of freedom of thought, of tolerance and appreciation of each other's opinions, which have prompted you to award to one of Holland's most prominent citizens this medal, and this action of yours will and must, I feel sure, render the relationship between the two nations still more affectionate, and lead us to feel still more the esteem and friendship we have for each other.

PRESIDENT CLARK: The Chair will again recognize Dr. Keller for a statement of the work of Mr. Edison and the introduction of Mr. Edison for the receipt of the Franklin Medal and Diploma.

DR. KELLER: Mr. President, in some respects the life and labors of the man who is present in person to receive from you the medal awarded him bear a resemblance to those of Professor Onnes, for, like the latter, he is an experimenter with a clear vision of the aims for which he strives, is endowed with an infinite capacity for taking pains, and with a truly marvellous perseverance in carrying everything he undertakes to a successful conclusion. But in other respects the stories of the life-work of the two medallists are widely different. While the activities of Onnes, as I have pointed out, have been directed almost exclusively toward augmenting our knowledge in a well-defined province of physical science, those of the second medallist extend over an almost inconceivable range of subjects from which his keen intellect and magic touch have wrested results that have ministered to the well-being, comfort, and pleasure of mankind.

Almost from the beginning of his career as an inventor his work attracted widespread interest, and I may say without fear of contradiction that no other inventor's name, either in this or any other country, has become so universally popular as his. His inventions and other achievements are so many that even their mere enumeration here would take up far more time than is allotted to me. In view, however, of the fact that the products of his genius have impressed themselves on the popular mind, and that an excellent and sympathetic narrative of his life has been written, it may suffice to briefly refer to the main achievements which the Institute desires to recognize by its highest award.

At the Centennial Exhibition, held in this city in 1876, some electrical inventions were among the objects that aroused the greatest interest, and it was during the decades that followed this event that we witnessed the great burst of activity in the electrical art to which we owe the creation of those vast industries which characterize our time as the Age of Electricity. In the galaxy of the great names that will ever be associated with this development not a few of the luminaries of the first magnitude were American inventors, and the one that seems to stand out brightest among them all, both as regards the number and value of his achievements, is our medallist.

He began his career as a train boy on a railroad and then became a telegraph operator. As a mere youth he made a number of inventions in connection with telegraphy, among which a stock-ticker became a great commercial success. During the following years we find our inventor engaged upon the development of the automatic telegraph and of duplex and quadruplex telegraphy, and then, after the Centennial year, he turned his attention to the solution of other electrical problems, rapidly forging his way to the front of the pioneers of that time. The enormous difficulties these men encountered in the solution of electrical problems can scarcely be appreciated by the electrical engineer of the present day.

After the invention of the telephone by Alexander Graham Bell it soon became apparent that something more powerful than the magneto transmitter was necessary, among other things, for its commercial success. This was supplied by our medallist when he invented the carbon transmitter, now in almost universal use. It is well known that it is to him also that we owe the invention of countless devices and methods in the art of telephony which have proved of the greatest value in the wonderful development of this industry.

In 1878 he invented the tinfoil phonograph, of which he constructed a number for exhibition purposes. This machine excited a great popular interest, but was succeeded by the wax cylinder machine which he later developed into one of the most perfect phonographs now on the market.

Among his greatest achievements, however, are the contributions he made to the art of electric lighting. He was indeed *facile princeps* among the creators of this industry. After moving to Menlo Park, N. J., in 1876, he was engaged there during a period of ten years on the development of his incandescent electric lamp dynamo, and system of low-pressure electrical distribution. On September 4, 1882, he started the Pearl Street Station in New York City, the first successful electrical station in America, an achievement which will ever remain a monument to his ingenuity, skill, and tireless energy.

It was followed by the construction of many similar plants both here and abroad.

I can only refer here in passing, as proofs of his marvellous resourcefulness and versatility, to his pioneer work on electric railways, his invention of the motion-picture apparatus, and his successful work on alkaline storage batteries, magnetic ore milling, the manufacture of Portland cement, and reënforced concrete construction. That he has lost none of his youthful energy and determination is evidenced in the rapidity with which he has reconstructed the enormous factories at Orange, N. J., destroyed only last December by a disastrous fire.

Writing in 1910, his biographers made an estimate of the extent of those industries which are either founded upon or affected by his inventions. They sum it up by saying that his work "has been one of the most potent factors in bringing into existence new industries now capitalized at nearly $7,000,000,000, earning annually over $1,000,000,000, and giving employment to an army of more than six hundred thousand people." These figures represent only the industries in this country, and are probably far below the actual values and numbers of to-day.

The wizard who has made these stupendous achievements is, of course, none other, Mr. President, than the peerless inventor known to all the world as Thomas Alva Edison, whom I now have the honor of presenting to you.

PRESIDENT CLARK: Mr. Edison, I have the honor, in the name of The Franklin Institute, upon the recommendation of its Committee on Science and the Arts, and in recognition of your distinguished services to humanity rendered in the field of science, to present to you the Franklin Medal and Diploma—the highest honor in the gift of the Institute.

PRESIDENT CLARK: The Chair will now recognize Dr. Hoadley, who will make a statement in connection with the founding of the Franklin Medal Fund.

DR. HOADLEY: Mr. President, one of the important functions of The Franklin Institute is that of awarding the various medals and premiums of which it is the custodian.

These awards form a notable list, including the Certificate of Merit, the Longstreth Medal, the John Scott Legacy Medal and Premium, the Potts Medal and the Elliott Cresson Gold Medal, the winning of any one of which is a mark of recognized merit.

All of these awards, however, are for some specific device, invention, or application of scientific principles.

The particular award that has hitherto not been available, and the lack of which has been seriously felt by the Institute, is one through the bestowal of which a man's life-work could be recognized and his achievements crowned.

It has been the fortunate experience of The Franklin Institute that the character of its work is so well recognized that whenever its needs have become known some friend has come forward to supply the deficiency.

The proverbial good fortune of the Institute did not desert it on this occasion, for Mr. Samuel Insull, President of the Commonwealth Edison Company of Chicago, a lifelong friend of Thomas A. Edison, and for many years his valued assistant, undertook to provide a fund sufficient to maintain a medal suitable for the desired purpose.

The character of this purpose is outlined in a statement in the deed of trust, indicating that the medal is to be called the Franklin Medal, that it is to contain a medallion of Benjamin Franklin, taken from his portrait by Thomas Sully, which is in the possession of The Franklin Institute, and that the award is to be made "to workers in physical science or technology, without regard to country, whose efforts, in the opinion of the Board of Managers of The Franklin Institute, have done most to advance physical science or its applications."

It is indeed fortunate that on this evening, when the first presentation of the Franklin Medal is made, its founder should be with us.

It has seemed fitting that on this occasion the appreciation of the Institute should be expressed by a testimonial to the donor, therefore, Mr. President, I have the honor to present to you Mr. Samuel Insull, the founder of the Franklin Medal.

PRESIDENT CLARK: Mr. Insull, I am commissioned by The Franklin Institute to formally thank you, in its name, for your contribution toward that encouragement of the mechanic arts which it is the function of the Institute to promote. Through your generosity the Institute is enabled, as never before, to express its appreciation of a life of eminent service in science.

As an evidence of our appreciation of the service you have thus rendered toward the promotion of the mechanic arts, the Institute asks you to accept this artist's proof of the medal founded by you, and bearing the immortal name of "Franklin."

Before delivering the address of the evening, "Electricity and Modern Industrial Growth," Mr. Insull expressed Mr. Edison's appreciation of the honor conferred upon him in awarding to him the Franklin Medal for his inventions and discoveries, and of his own appreciation of the privilege he felt had been his in contributing to the Institute's means of recognizing the work of great scientists and inventors.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, June 2, 1915.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 2, 1915.

MR. G. H. CLAMER *in the Chair.*

The following reports were presented for first reading:

No. 2628.—John Underwood and Company's Combined Typewriting and Calculating Machine.

No. 2636.—Lenker's L-E-Vation Rod.

No. 2643.—Street Locomotive Stoker.

R. B. OWENS,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, June 9, 1915.*)

RESIDENT

DR. ENOCH KARRER, United Gas Improvement Company, 3101 Passyunk Avenue, Philadelphia, Pa.

MR. E. F. KINGSBURY, United Gas Improvement Company, 3101 Passyunk Avenue, Philadelphia, Pa.

NON-RESIDENT

MR. H. A. TOULMIN, JR., Schwind Building, Dayton, Ohio.

CHANGES OF ADDRESS.

MR. CHARLES A. BRINLEY, The American Pulley Company, 4200 Wissahickon Avenue, Philadelphia, Penna.
MR. CLARENCE R. CLAGHORN, President, Durham Colliery Company, Durham, Washington.
MR. PARKE D. MASSEY, Pasto, Colombia, South America.
MR. GEORGE A. ORROK, Lee, Mass.
PROF. I. M. RAPP, Phœnixville, R. F. D. No. 2, Penna.
MR. W. S. RUGG, care of Crescent Athletic Club, Shore Road, Brooklyn, N. Y.
MR. W. F. THORNTON, Mechanicsburg, R. R. No. 2, Cumberland County, Penna.

NECROLOGY.

Colonel Caldwell K. Biddle was born at Rio de Janeiro, Brazil, in 1862, and died in Philadelphia on June 2, 1915.

His early education was secured in private schools in Philadelphia. Later he entered St. Paul's School, Concord, N. H., and in 1884 graduated from the Academic Department of the University of Pennsylvania, and in 1886 from the Law School. Soon after this he was admitted to the bar and began the practice of law.

Colonel Biddle took a great interest in military affairs, and for a number of years was a member of the First Troop, Philadelphia City Cavalry. Later he became connected with the Third Regiment, National Guard of Pennsylvania, as second lieutenant of Company H, and during the Spanish War served in Cuba as Captain of the company. In 1900 he was appointed Regimental Inspector of Rifle Practice, in 1901 he became Second Major, and in 1911 he was elected Colonel of the Regiment.

Colonel Biddle was a member of the University Club and other organizations.

He became a life member of The Franklin Institute in 1900.

Lewis Metzler Clement was born at Niagara, Ontario, Canada, August 12, 1837, and died at Hayward, Cal., October 29, 1914.

He was employed in the construction of the Montreal Water Works and was engineer in charge of construction of the Welland Railway. He was also engaged in the construction of the Port Dover and Hamilton Railway, and later was employed by the Ohio and Mississippi Railroad.

In the spring of 1862 he was engaged by the Central Pacific Railroad as assistant chief engineer. At this time the railroad was being built from Sacramento to Ogden, Utah, and Mr. Clement was in charge of the construction of the line over the Sierra Nevada Mountains. He put in operation the first electric patrol system for railroads, which covered a distance of fifty miles, through snow sheds and tunnels.

He designed the first emigrant sleeping car used by the railroads of to-day, and introduced many notable improvements in the design and construction of steam, cable, and electric railways.

Mr. Clement was appointed chief engineer of the Atlantic and Pacific

Railroad in 1881, and afterwards chief engineer of the Pacific Improvement Company of California, in the construction of cable and electric railways. He was also consulting engineer of the Southern Pacific Company and the Leland Stanford, Jr., University.

Mr. Clement was elected a member of The Franklin Institute in 1899.

Stuart Wood, 1620 Locust Street, Philadelphia.

LIBRARY NOTES.

PURCHASES.

BENOIT, J. R., AND GUILLAUME, C. E.—La mesure rapide des bases geodesiques. 1908.

COX, JOHN.—Beyond the Atom. 1913.

ELLIOTT, CHARLES E.—Engineering for Land Drainage. 1913.

MARSHALL, ARTHUR.—Explosives, Their Manufacture, Properties, Tests, and History, 1915.

MILLS, W. T.—American School Building Standards. 1915.

MORSE, WILLIAM F.—Collection and Disposal of Municipal Waste. 1908.

MYERS, D. F.—Preventing Losses in Factory Power Plants. 1915.

National Association of Cement Users.—Proceedings, vol. 8. 1912.

PHILIP, JAMES C.—Physical Chemistry; its Bearing on Biology and Medicine. 1913.

RIDEAL, SAMUEL AND E. K.—Water Supplies: Their Purification, Filtration, and Sterilization. 1915.

STECHER, G. E.—Cork: its Origin and Industrial Uses. 1914.

THOMPSON, S. P.—Rose of the Winds: Origin and Development of the Compass Card. 1913.

TOMKINS, ERNEST.—Science of Knitting. 1914.

WEIMARN, P. P. VON.—Zür lehre von den Zuständen der Materie. 2 volumes. 1914.

West Virginia Geological Survey.—Logan and Mingo Counties—Report and Maps. 2 volumes. 1914.

WILEY, H. W.—Principles and Practice of Agricultural Analysis. Part 2, Fertilizers and Insecticides. 1908.

GIFTS.

Beghin, A., Regle a Calculus, Modele Special. Paris, 1899. (From Mr. L. E. Picolet.)

Boston Transit Commission, Twentieth Annual Report. Boston, Mass., 1914. (From the Commission.)

British Journal Photographic Almanac and Photographer's Daily Companion. London, 1915. (From Mr. L. E. Picolet.)

Canada Department of Mines, Memoir 30, The Basins of Nelson and Churchill Rivers, 1913; Memoir 38, North American Cordillera, part i, 1912; Memoir 56, Geology of Franklin Mining Camp, British Columbia; Memoir 59, Coal Fields and Coal Resources of Canada. Ottawa, 1915. (From the Department.)

Canada Department of Trade and Commerce, Monthly Report, February. Ottawa, 1915. (From the Department.)

Canadian Society of Civil Engineers, Transactions, vol. xxviii, part ii, 1914. Montreal, 1915. (From the Society.)

Catholic University of America, Year-Book. Washington, D. C., 1915. (From the University.)

College of William and Mary, Catalogue, 1914–1915. Williamsburg, Va., no date. (From the College.)

Cullman Wheel Company, Catalogue No. 10 of Sprockets. Chicago, Ill., no date. (From the Company.)

Dodge Sales and Engineering Company, Catalogue of Gears. Mishawaka, Ind., no date. (From the Company.)

Dominion Bridge Company, Ltd., Catalogue S-1 of Bridges and Steel Structures. Montreal, Can., 1915. (From the Company.)

Duplex Hanger Company, Inc., Catalogue of Hangers. Cleveland, Ohio, no date. (From the Company.)

Eynon-Evans Manufacturing Company, Catalogue No. 10 of Hydraulic and Special Machinery. Philadelphia, no date. (From the Company.)

General Fireproofing Company, The Fireproofing Hand Book. Youngstown, Ohio, 1915. (From the Company.)

Georgia Geological Survey, Bulletin No. 30, A Preliminary Report on the Feldspar and Mica Deposits of Georgia. Atlanta, 1915. (From the Survey.)

Golden-Anderson Valve Specialty Company, Catalogue No. 18 of Steam and Water Specialties. Pittsburgh, Pa., 1915. (From the Company.)

Illinois State Geological Survey, Bulletin of Illinois Coal Mining Investigations. Urbana, 1915. (From the Survey.)

Institution of Engineers and Shipbuilders in Scotland, Transactions, vol. lvii. Glasgow, 1914. (From the Institution.)

Instituto y Observatorio de Marina de San Fernando, Almanaque Nautico, 1916. San Fernando, Spain, 1914. (From the Instituto.)

Jablonski, E., Cours D'Arithmetique. Paris, 1888. (From Mr. L. E. Picolet.)

Keeler, E. Company, Catalogues of Return Tubular Boilers and Water Tube Boilers. Williamsport, Pa., no date. (From the Company.)

Link-Belt Company, Data Book No. 125. Chicago, Ill., 1915. (From the Company.)

Liverpool Engineering Society, Transactions, vol. xxxv. Liverpool, England, 1914. (From the Society.)

Locke Regulator Company, Catalogue N of Regulating Devices. Salem, Mass., no date. (From the Company.)

Louisiana State University, Catalogue. Baton Rogue, 1915. (From the University.)

Manchester Steam Users' Association, Thirty-First Annual Report upon the Working of the Boiler Explosions Act, June 1912–June, 1913. Manchester, England, no date. (From the Chief Engineer.)

Mead-Morrison Manufacturing Company, Catalogue "S" 2 of Steam Hoists. Boston, no date. (From the Company.)

Missouri Botanical Garden, Annals, vol. ii, Nos. 1 and 2. St. Louis, Mo., 1915. (From the Board of Trustees.)

Morse Twist Drill and Machine Company, Catalogue of Drills, Reamers, Dies, Machinery and Machinists' Tools. New Bedford, Mass., 1915. (From the Company.)

National Commercial Gas Association, Lessons on the Utilization of Gas Appliances, I to X, part iii, Practical Educational Courses; Elementary Principles of Combustion and Utilization of Energy, part i; Units of Light and Illumination and Principles of Light Distribution, part ii; Tables and Glossary, part iii; The Gas Equipment of the Home. New York, no date. (From Mr. Louis Stotz, Secretary.)

New Jersey Geological Survey, Bulletin 13, Indian Habitations in Sussex County, New Jersey; Bulletin 14, The Geology of New Jersey. Union Hill, N. J., 1915. (From the Survey.)

New York Department of Efficiency and Economy, Annual Report. Albany, 1915. (From Prof. Arthur H. Blanchard.)

North Western Expanded Metal Company, Designing Data for Reinforced Concrete. Chicago, 1914. (From the Company.)

Oberlin College, Bulletin and Annual Catalogue. Oberlin, Ohio, 1915. (From the College.)

Ohio Agricultural Experiment Station, Technical Bulletin No. 5, Phosphorus Compounds in Animal Metabolism. Wooster, 1914. (From the Station.)

Ohio Locomotive Crane Company, Catalogue of Locomotive Cranes. Bucyrus, no date. (From the Company.)

Ontario Department of Agriculture, Forty-fifth Annual Report of the Entomological Society, 1914. Toronto, 1915. (From the Department.)

Oregon State Immigration Commission, Oregon Almanac, 1915. Salem, 1914. (From the Portland Chamber of Commerce.)

Pennsylvania Department of Forestry, Report, 1912–1913. Harrisburg, 1915. (From the State Librarian.)

Pennsylvania State College, Report, 1912–1913. Harrisburg, 1914. (From the State Librarian.)

Pennsylvania Topographic and Geologic Survey Commission, Report No. 7. Harrisburg, 1913. (From the State Librarian.)

Philadelphia City Trusts, Forty-fifth Annual Report of Board of Directors, 1914. Philadelphia, 1915. (From the Board.)

Philadelphia Department of Public Works, Report on the Collection and Treatment of the Sewage of the City of Philadelphia. Philadelphia, 1914. (From Mr. George S. Webster.)

Philadelphia Electric Company, Current News, vols. 7–8 and 9–10, 1913–1914. Philadelphia, no date. (From the Company.)

Pridmore, Henry E., Catalogue No. 8 of Molding Machines. Chicago, Ill., no date. (From Mr. H. E. Pridmore.)

Society for the Promotion of Engineering Education, Proceedings, vol. xxii, 1914. Pittsburgh, 1915. (From Dr. R. B. Owens.)

Tokyo Imperial University, Calendar, 1913–14. Tokyo, no date. (From the University.)

United States War Department, Report of the Tests of Metals and Other Materials, 1914, Washington, 1915. (From the Department.)

University of Michigan, Catalogue. Ann Arbor, 1915. (From the University.)

University of Oklahoma, General Catalogue. Norman, 1915. (From the University.)

Victorian Institute of Engineers, Proceedings, vol. xiii. Melbourne, 1913. (From the Society.)

Vulcan Engineering Sales Company, Catalogue No. 3 of Riveters. Chicago, Ill., 1915. (From the Company.)

Watson-Stillman Company, Catalogue No. 92 of Forcing Presses. New York, no date. (From the Company.)

Wesco Supply Company, Catalogue No. 200 of Electrical Goods. St. Louis, no date. (From the Company.)

Western Australia Geological Survey, Bulletin Nos. 56, 57, 59, and 61. Perth, 1914. (From the Survey.)

Western Society of Engineers. Year Book. Chicago, Ill., 1915. (From the Society.)

BOOK NOTICES.

THE CHEMISTRY OF THE CYANOGEN COMPOUNDS AND THEIR MANUFACTURE AND ESTIMATION. By Herbert E. Williams. Philadelphia, P. Blakiston's Son & Co., 1915. Pages i–viii, 406 and Indexes. 8vo. Price, $3.50.

The introductory paragraphs of this work give a short history of the development of our knowledge of an interesting and important group of substances which were long considered as one of the connecting links between organic and inorganic compounds, at least so far as descriptive chemistry is concerned. From this historical summary we learn that the first step was the production of Prussian blue by Driesbach in 1704, and that Macquer, about a half century later, obtained potassium ferrocyanide. An interesting sidelight is thrown on the state of chemistry at that time by the fact that Macquer called the substance "phlogisticated alkali." Scheele obtained hydrogen cyanide in 1782; Gay Lussac prepared free cyanogen in 1815.

The work is divided into three sections, devoted, respectively, to: Chemistry of the cyanogen compounds, manufacture and applications of cyanogen compounds, analysis of cyanogen compounds. Many of the cyanides, ferro- and ferricyanides are described, and much information given concerning other complicated derivatives (cobalti- and platinocyanides), thiocyanates and fulminates. To the chemist who has not followed closely the development of this department, the references to the carbonylferrocyanides will be somewhat astonishing. Ammonium carbonylferrocyanide, for example, is $(NH_4)_3Fe(CN)_5(CO)3H_2O$, and when we come to the diethylaniline and dimethylaniline derivatives the complication is great. It is interesting to write the formula of the ammonium compound empirically, and note how incomprehensble it is: $C_6H_{18}N_8FeO_4$.

A highly commendable feature is the correctness of nomenclature. It is up to date. Such solecisms as "cyanate of potash" and "potassium sulphocyanide," which are so common in present-day works of British provenance, are not found in this work. It is a valuable contribution to an important and complex department of applied chemistry.

HENRY LEFFMANN.

EXPLOSIVES: THEIR MANUFACTURE, PROPERTIES, TESTS, AND HISTORY. By Arthur Marshall, A.C.G.I., F.I.C., F.C.S., Chemical Inspector, Indian Ordnance Department. Philadelphia, P. Blakiston's Son & Co., 1915. 605 pages and indexes. 8vo. Price, $7.

Few works of a purely technical character could just now attract more general attention, but it is not of any popular interest that this review should speak. The work is by an expert and represents a needed addition to the literature of an extensive and important department of applied chemistry. The attention of people at large is usually directed to the use of explosives for destructive purposes, but those familiar with the subject know that by far the more important use is in constructive operations, in which, at most, the destruction is only preliminary to improvement.

The work is comprehensive, including many details of the manufacture of the materials used in the making of explosives, as well as the process of manufacture of all leading types. Considerable attention is given to the theoretical side of the science, and a summary of the history of the development of explosives as used in war. In the latter we find, as might be expected, that some of the "Tales of our Grandfathers" are without basis, notably the story that the Chinese used gunpowder at a very early date. Mr. Marshall, however, shows that they did use potassium nitrate about the middle of the eighteenth century. The legend as to the great antiquity of Chinese gunpowder seems to have been due to mistranslations—depending on misunderstandings—by the Jesuit missionaries. Roger Bacon knew methods of preparing explosives with charcoal, sulphur, and saltpetre. Incidentally, Mr. Marshall's summary shows the truth of the current saying that gunpowder was invented by a monk and the percussion cap by a minister.

On taking up the book the reviewer was reminded of the opening lines of Macaulay's review of Nares's "Life of Lord Burghley," in which are given the volume and weight of the book. Mr. Marshall's book is no *vade mecum*. It has a volume of about two litres and weighs over two kilos. Bulk and weight are due largely to the use throughout of heavy surfaced paper, a procedure that the reviewer thinks might easily have been avoided.

A short article on fireworks is included, but no mention is made of photographic flash-powders. It seems to the reviewer that these deserve considerable attention. They are extensively used, many forms have been prepared, and much destruction of life and property has been occasioned by them. In Philadelphia alone nearly a dozen deaths have been caused by the mixtures. A good account of preparations now offered by leading firms should certainly be included in a work of such comprehensive character as this.

A great disappointment is the neglect of the modern standard nomenclature of chemical compounds. It is surely time that such terms as "chlorate of potash," "acetate of lime," and "chloride of sodium" should be avoided in a scientific work.

A paragraph of much present interest to American readers is the notice of the Louisiana sulphur mines. The deposits are at such a depth as to render ordinary mining methods too expensive, but by an ingenious use of high steam the sulphur is brought to the surface and collected. The perfection of the method is due to Hermann Frasch. Until these mines were opened the world's supply of free sulphur was almost entirely from Italy, but several hundred thousand tons are produced each year in Louisiana, and the United States has not only enough for itself, but exports such large amounts that the Sicilian mines became unprofitable. The Italian Government has taken over the operation of these, and Mr. Marshall states that the present condition of the workers is better than ever before.

HENRY LEFFMANN.

SPENCER FULLERTON BAIRD, A BIOGRAPHY, INCLUDING SELECTIONS FROM HIS CORRESPONDENCE WITH AUDUBON, AGASSIZ, DANA AND OTHERS. By William Healey Dall, A.M., D.Sc. Philadelphia, J. B. Lippincott Company, 1915. 450 pages, 19 illustrations. 8vo. Price, $3.50.

The subject of this work was the second secretary of the Smithsonian Institution, and organizer and first commissioner of the United States Commission of Fish and Fisheries. He died at Wood's Hole.

The data were largely collected by his daughter, Miss Lucy Hunter Baird, and to Dr. Dall was committed the task of selecting, arranging, and preparing them for publication. The forepart of the book contains a summary of the genealogy, and some incidents of the early life. The childish traits and early experiences of those who have become great are always of interest, and usually exemplify the truth of the adage that "truth is stranger than fiction." Perhaps the vividness of such recital is better preserved in an autobiography, if the editors have not used the blue pencil freely.

The letters that pass between distinguished men and women of similar tastes throw much light on the development and methods of human thought, yet it seems probable that, except in the case of those who have profoundly modified the general course of human events, comparatively few care to read the collection. By founding the Commission of Fish and Fisheries, Baird did much greater service to mankind than Peary did by reaching the Pole, or Roosevelt by shooting game in Africa and South America, yet thousands of people know of the exploits of the two latter for one who knows the service of the former.

HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

Test Methods for Steam Power Plants: A Reference Book for the Use of Power-station Engineers, Superintendents and Chemists, by Edward H. Tenney, B.A., M.E. 224 pages, illustrations, 12mo. New York, D. Van Nostrand Company, 1915. Price, $2.50 net.

Theatres: Their Safety from Fire and Panic, Their Comfort and Healthfulness, by Dr. William Paul Gerhard, C.E. Second edition, 110 pages, 12mo. New York, The Baker and Taylor Company, 1915.

Canada Mines Department, Mines Branch: Petroleum and Natural Gas Resources of Canada, vol. i, by Frederick G. Clapp and others. 378 pages, illustrations, plates, tables, maps, 8vo. Ottawa, Government Printing Bureau, 1914.

Michigan State Board of Health: Forty-first Annual Report of the Secretary for the fiscal year ending June 30, 1913. 183 pages, illustrations, 8vo. Lansing, State Printers, 1914.

A Text-book of Dispersoidology: Modern Colloidal Chemistry, by A. Janek. (In the Russian language.) 248 pages, illustrations, portraits, plates, 8vo. Petrograd, 1915.

U. S. Department of Agriculture: Farmers' Bulletin No. 657, The Chinch Bug, by F. M. Webster, in charge of cereal and forage insect investigations. 28 pages, illustrations, 8vo. No. 664, Strawberry Growing in the South, by H. C. Thompson, horticulturist, Office of Horticultural and Pomological Investigations. 20 pages, illustrations, 8vo. Washington, Government Printing Office, 1915.

Pennsylvania Topographic and Geologic Survey: Report No. 2, Geologic Map of Southwestern Pennsylvania. 29 pages, maps, 8vo. No. 8A, The Mineral Production of Pennsylvania, 1911, Coal and Coke. 139 pages, 8vo. No. 8C, Clay and Clay Products, 1911. 51 pages, 8vo. No. 8E, Quarry Products, Granite, Trap Rock, Sandstone, Bluestone, Marble, Limestone, Lime. 84 pages, 8vo. Harrisburg, Telegraph Printing Company, 1915.

U. S. Bureau of Mines: Technical Paper 88, Mineral Technology 6, The Radium-uranium Ratio in Carnotites, by S. C. Lind and C. F. Whittemore, 29 pages, 8vo. Technical Paper 95, Mining and Milling of Lead and Zinc Ores in the Wisconsin District, Wisconsin, by Clarence A. Wright. 39 pages, illustrations, 8vo. Technical Paper 101, Permissible Explosion-proof Electric Motors for Mines; Conditions and Requirements for Test and Approval, by H. H. Clark. 17 pages, illustrations, 8vo. Monthly Statement of Coal-mine Fatalities in the United States, March, 1915, compiled by Albert H. Fay. 12 pages, 8vo. Washington, Government Printing Office, 1915.

Calculation of Illumination with Indirect or Semi-indirect Light Sources. RICHARD C. POWELL. (*Electrical World,* vol. 65, No. 23, 1463.)—Calculation from the photometric curve and height of a source of light is a well-known and commonly-used method for predetermining the distribution and intensity of illumination from a direct light source. But when indirect or semi-indirect units are employed, the usual course is to rely upon judgment or a preliminary test which often is not convenient. In the method of calculation developed it is necessary to know only the photometric curve, the coefficient of reflection for the secondary source (usually the ceiling), the distance of the unit below the ceiling, and the height of the ceiling above the plane of illumination. While this method is not so simple as in the case of direct units, still it is believed to be sufficiently so to make it of considerable value to those planning lighting installations.

Outline of Method.—The light unit produces on the ceiling a secondary light source in the form of a circular disk, generally of non-uniform intensity. This disk may, however, be considered as made up of a number of circular annuli or rings of uniform intensity of illumination. The effect may also be considered the same as that which would be produced by a number of uniformly-illuminated concentric disks of varying radii. By calculating each disk separately and adding the results there is obtained approximately the illumination due to the ceiling. By taking a sufficiently large number of disks we may make the approximation as close as desired, but in practice it is usually sufficient to take four.

CURRENT TOPICS.

Production and Shipments of Portland Cement, 1914.—Figures gathered by United States Geological Survey show decrease in both quantity and value of output. The total production of Portland cement in the United States in 1914, according to Ernest F. Burchard, of the United States Geological Survey, was 88,230,170 barrels, valued at $81,789,368; the production for 1913 was 92,097,131 barrels, valued at $92,557,617. The output for 1914 represents a decrease in quantity of 3,866,961 barrels, and a decrease in value of $10,768,249. The value assigned to the production is computed on the basis of 92.7 cents a barrel, or the average value of the Portland cement shipped in 1914.

The shipments of Portland cement from the mills in the United States in 1914 amounted to 86,437,956 barrels, valued at $80,118,475, compared with 88,689,377 barrels, valued at $89,106,975, shipped in 1913. This represents a decrease in quantity of 2,251,421 barrels, and in value of $8,988,500. The average factory price per barrel in bulk for the whole country in 1914 was 92.7 cents, compared with $1.005 in 1913, a decrease of 7.8 cents a barrel. This price is about 11.8 cents higher than the average price in the Lehigh District and is near the average price in New York, Illinois, Iowa, the Southeastern States, and the Plains States, but falls 42.5 cents below the average price received in Utah, where Portland cement brought the highest figure during the year.

Among the States there were unimportant changes in rank as cement producers. Pennsylvania and Indiana held first and second places respectively, as for many years, but both of these large cement-producing States suffered an appreciable reduction of output. In 1913 the output of California exceeded that of New York and Illinois, but in 1914 this State dropped from third to fifth place. New Jersey dropped from seventh to ninth place, having been passed by both Michigan and Iowa in 1914. The State of Kansas, which has attracted considerable attention in the cement world, first because of the rapid development of the industry within its borders on account of the proximity of abundant supplies of suitable raw material and cheap natural gas, and later because of the waning of the gas supply and the consequent increase in cost of manufacture of cement which resulted in curtailment of output, maintained its rank of tenth among cement producers and suffered but little reduction of output, although the price of cement here fell considerably below the average. Iowa and Ohio both showed gratifying increase in output and appear also to have kept prices up more successfully than many other States. In the Far West, in Washington, conditions were brought into better balance by a considerable curtailment of production and an increase in shipments, although prices fell heavily; in Utah production was largely and shipments slightly increased, and prices were also increased. The only other States showing increase of prices were New Jersey and Texas.

Of the twelve commercial districts into which the United States is divided, there was an increase in production in five—New York, Michigan-northeastern Indiana, Maryland-West Virginia, Iowa-Missouri, and the Rocky Mountain States—and an increase in shipments in seven—New York, Ohio-western Pennsylvania, Michigan-northeastern Indiana, Kentucky-southern Indiana, Maryland-Virginia-West Virginia, Iowa-Missouri, and the Rocky Mountain States. There were decreases in production in seven districts—Lehigh, Ohio-western Pennsylvania, Kentucky-southern Indiana, Illinois-northwestern Indiana, Tennessee-Alabama-Georgia, Great Plains, and Pacific coast—and decreases in shipments in five districts—Lehigh, Illinois-northwestern Indiana, Tennessee-Alabama-Georgia, Great Plains, and Pacific coast. The largest percentage of increase of production was reported from New York, but the increase in shipments in that district was only half as great. The districts that showed the heaviest percentages of decrease in both production and shipments were the Tennessee-Alabama-Georgia district and the Pacific coast.

Production of Pyrite and Sulphuric Acid in 1914.—The production of pyrite in the United States in 1914, according to W. C. Phalen, of the United States Geological Survey, was 336,662 long tons, valued at $1,283,346. In 1913 the production was 341,338 long tons, valued at $1,286,084. There was a decrease, therefore, in 1914 of 4676 long tons in quantity, or slightly more than one per cent., and of $2738 in value, or but one-fifth of one per cent.

Virginia is the leading State in both production and value. The output of this State diminished slightly in 1914 as compared with 1913. The output in California showed a slight gain. There was a substantial gain in the production in New York, which, though ranking third among the States in production, stands second in value. In Illinois, where pyrite is a by-product obtained in connection with coal mining, the output more than doubled compared with 1913. In Wisconsin there was a decreased production. In Georgia there was a slight increase. In both Ohio and Missouri there was a decline in production, and in Indiana, where, as in Illinois and Ohio, the pyrite is obtained in connection with coal mining, there was a slight increase as compared with 1913.

Imports of Pyrite.—The imports of pyrite for consumption during the calendar year 1914 were 1,026,617 long tons, valued at $4,797,326. These figures show a notable increase compared with the imports of 1913, which were 850,592 long tons, valued at $3,611,137. The increase in imports in 1914 amounted to 176,025 long tons, and in value to $1,186,189.

Production of Sulphuric Acid.—According to actual returns for the year 1914, the production of sulphuric acid in the United States was 3,762,417 short tons of 50° acid, valued at $24,163,331. This is exclusive of 21,993 short tons of fuming acid, valued at $316,596, but the figures given above include by-product acid—that is, acid obtained in the smelter industry. The acid produced at copper and zinc smelters in 1914 amounted to 950,798 short tons of 50° acid, valued at $5,190,293. The entire production of acid by grades is tabulated below:

PRODUCTION OF SULPHURIC ACID IN THE UNITED STATES IN 1914 BY GRADES, IN SHORT TONS.

Grade	Quantity	Value	Price per ton
50° Baumé	1,628,402	$ 9,712,056	$ 5.96
60° Baumé	551,955	3,376,242	6.12
66° Baumé	916,192	10,509,471	11.47
Other grades	65,890	882,158	13.39
Total	3,162,439	$24,479,927	$ 7.74
Total reduced to 50° Baumé acid	*3,762,417	*24,163,331	6.42

* Exclusive of 21,993 short tons of fuming acid, valued at $316,596.

PRODUCTION OF SULPHURIC ACID FROM COPPER AND ZINC SMELTERS IN 1913 AND 1914, IN SHORT TONS (REDUCED TO 60° BAUMÉ ACID).*

Source	1913			1914		
	Quantity	Value	Price per ton	Quantity	Value	Price per ton
Copper smelters	336,019	$2,205,627	$6.56	348,727	$2,215,690	$6.35
Zinc smelters	296,218	2,140,645	7.23	411,911	2,974,603	7.22
Total	632,237	$4,346,272	$6.87	760,638	$5,190,293	$6.82
Total acid reduced to 50° Baumé	790,296	....	.....	950,798	....	.....

* The acid reported to the Survey includes strengths rated at 50°, 53°, 55°, 60°, and 66° Baumé, and a small quantity of electrolyte and oleum. All strengths, with the exception of the electrolyte, have been reduced to both 50° and 60° Baumé, as given in the table.

Developments in Heating and Ventilation. A. H. BARKER. (*Journal and Transactions of the Society of Engineers (Incorporated)*, vol. vi, No. 5.)—It is an undeniable fact that a room filled with air which, so far as chemical analysis can detect, is absolutely pure may feel very stuffy. For instance, the House of Commons, on the ventilation of which the author has experimented for many months for the Committee of the House, the air in the debating chamber is, chemically speaking, as pure as in any room in the world. Fresh air simply pours into it in extravagant volumes. In a moderately full house there are no less than 13,000 cubic feet of air supplied per head per hour. Yet it produces, without any possible doubt, the effects which we are accustomed to think of as associated with defective ventilation—lassitude, sleepiness, infection, and so forth. Complaints are loud and quite general. A room may, on the contrary, feel fresh and sweet in which, judged by chemical standards, the air is very bad. The author has analyzed air containing 25 volumes per 10,000 of CO_2 which felt as fresh as a spring morning, although 10 volumes is regarded as the extreme allowable impurity in current science. There must be some combination of chemical or physical conditions which accounts for the effect, so far as it is objective; when it is purely subjective, of course, it is impossible to analyze the effect. Nobody up to the present has ventured to specify what is that combination.

Examining X-ray Plates by Mercury-vapor Lamps. ANON. (*Electrical World*, vol. 65, No. 23, 1475.)—For the minute examination of details of structure in fabric many advantages are claimed for monochromatic light, since with it all rays which make up the image are brought together in the "plane" of the retina without the possibility of effects of color aberration. Hence vision becomes much "sharper." An interesting application of this advantage is in its use in hospital X-ray wards for the inspection of skiagraph negatives by the surgeons. A large installation of this kind was recently completed at the Cook County Hospital, Chicago. According to the physician in charge, much sharper inspection, and consequently better diagnosis of the faint images and shadows of the negative, is secured by the monochromatic light of the mercury arc than with the continuous-spectrum illumination formerly obtained from incandescent-filament units.

A Galvanic Cell Which Reverses its Polarity when Illuminated. A. A. C. SWINTON. (*The Physical Society of London*, vol. xxvii, part iii.)—If two plates—one of zinc and the other of tinned copper coated on one surface with selenium and varnished with enamel over the remainder of its surface—are immersed in tap-water, the electric current through a galvanometer connected to the plates shows that in the dark the zinc is electro-positive to the selenium, while the result of light falling on the selenium is to increase the effect. If, however, instead of zinc, carbon or copper is employed for the non-coated plate, the interesting result is obtained that, while the selenium proves to be electro-positive to the carbon or copper in the dark, it immediately becomes electro-negative to carbon or copper the moment it is illuminated, this being easily shown by the deflections of the galvanometer in contrary directions as the light is turned on or off.

The Distribution of Heat in the Cylinder of a Gas Engine. A. H. GIBSON and W. J. WALKER. (*The Journal of the Institution of Mechanical Engineers,* No. 5, 1915.)—The paper deals with the results of a series of experiments on heat-flow in a gas-engine cylinder as affected by the variation of speed, load, compression ratio, and gas mixture. The principal point under investigation was to determine the effect of turbulence on this heat-flow. The trials were carried out on a "National" gas-engine of 30 b.h.p., peculiarly well suited for the investigation, a special water-jacketing arrangement being provided whereby exhaust and barrel heat losses are separated. Some 130 trials were carried out. The most important points brought out in the investigation may be summarized as follows: *The mechanical efficiency* (1) diminishes as the ratio air: gas increases, (2) diminishes as the speed increases, (3) is sensibly independent of compression ratio. *The thermal efficiency,* measured on the indicated horse-power, (1) attains a maximum with an air : gas mixture of about 10 : 1; (2) diminishes as the speed increases. *Percentage exhaust losses* (including heat to exhaust-valve jacket) (1) diminished as the load increases; (2) diminish very slightly as the ratio air: gas increases; (3) increase as speed increases; (4) increase as the compression ratio increases. *Percentage jacket losses* (barrel and breech only) (1) increase with the load; (2) diminish as the ratio air: gas increases; (3) diminish as the speed increases; (4) are sensibly independent of compression ratio. It is interesting to note that the rate at which heat is lost to the barrel-jacket is much greater at high speeds than at low speeds, notwithstanding the lower explosion temperatures which accompany the higher speeds. This effect is apparently due to the predominating influence of turbulence, causing an increase in the effective conductivity of the working fluid. The final portion of the paper describes how heat balance sheets were made up to the end of expansion for each test by obtaining the internal energy of the fluid at the end of expansion. An interesting point brought out by these balance-sheets appears in the fact that with ordinary mixtures and compression ratios they agree very well with those of the ordinary commercial type of engine, obtained by measuring the i.h.p. and jacket heat and estimating exhaust losses by difference. For fairly rich mixtures and lower compression ratios, however, the agreement is not so good, the jacket losses as usually measured in an ordinary engine always being in excess of those more correctly computed from the internal energy of the gas.

Noise in Gearing. ANON. (*English Mechanic,* vol. ci, No. 2616, 325.)—It is not always easy to trace noise to its source, for it is often the combined effect of several small individual causes, and not infrequently an incorrect conclusion is reached and a wrong remedy applied. Two manufacturers, both producing a similar machine, claim to have minimized noise by entirely opposite means, both maintaining their own solution the best possible. One had adopted an extra-long tooth, the other an extra-short tooth. The author points out that the most prolific cause of noise is inaccuracy of workmanship, both in the gears themselves and in their mounting. He describes at considerable length precaution to be observed in attaining accuracy essential to good results, whatever be the form of tooth adopted or the material.

The Second Pan-American Scientific Congress.—During the present year two important Pan-American gatherings convene in Washington under the auspices of the Government of the United States. The first of these, the Pan-American Financial Conference, occurred the week of May 24, 1915. Of greater interest to the educational world, however, is the Scientific Congress that will convene in Washington, beginning December 27, 1915, concluding its sessions January 8, 1916. The first congress of this name was held in Santiago, Chile, in 1908. This congress was well attended by visiting delegates from the United States. On its adjournment, entirely unsolicited on the part of the latter, Washington was designated as the place of meeting of the second congress. The Scientific Congress will concern itself with the constructive discussion of the grave economic problems with which the western hemisphere has been confronted by the war in Europe that invite the serious attention of scientists and experts in the various fields of applied science, as well as with advances in the domain of pure science made since the last congress in Santiago, Chile. Science is comprehensively defined by the congress, and includes, authropology, astronomy, agriculture, education, engineering, jurisprudence, chemistry, medical science, and commerce. The significance of the congress through the importance of the above subjects is greatly enhanced through the international reputation of the persons chosen to arrange for the program of the different sections of the congress, most of whom have an intimate first-hand acquaintance as well with the local resources, development, and scientific interest in the various Latin-American countries.

PRESS OF
J. B. LIPPINCOTT COMPANY
PHILADELPHIA

JOURNAL
OF
THE FRANKLIN INSTITUTE

DEVOTED TO SCIENCE AND THE MECHANIC ARTS

VOL. CLXXX AUGUST, 1915 No. 2

THE EFFECT OF THE END CONNECTIONS ON THE DISTRIBUTION OF STRESS IN CERTAIN TENSION MEMBERS.[1]

BY

CYRIL BATHO, B.Eng., M.Sc.,

Assistant Professor of Applied Mechanics, McGill University, Montreal, Canada.

INTRODUCTION.

THE experimental study of the distribution of stress in structural members has received considerable attention in recent years. The experiments of American investigators upon actual structures are well known. Most of these investigations, however, have been made with strain gauges, such as the Howard and Berry, which, while excellently adapted to the more or less rough determination of average strains in members of actual structures, are scarcely suited to refined measurement of the distribution of strain in a member subjected to stresses which vary considerably over the cross-section. Thus the analysis of the distribution of stress in single or built-up structural members and its modification due to different types of end connections has scarcely received the attention which it deserves from its practical importance. The optical determination of complex stress distribution in transparent materials by the use of polarized light as developed by Coker, Mesnager, Hönigsberg and others,[2] although giving accurate results within its range, does not appear to be

---

[1] Communicated by Professor H. M. Mackay.

[2] See British Association Report, 1914.

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

Copyright, 1915, by THE FRANKLIN INSTITUTE.

capable of extension to the investigation of built-up members, as the actual end conditions, connections between the parts, etc., cannot be correctly imitated in glass or xylonite models. The thermoelectric method would appear to be more promising, but has not yet been sufficiently investigated. For the present it would seem as if reliance must be placed upon measurement with some form of extensometer. Most extensometers, however, measure only the average stress over a considerable length, are bulky and inconvenient, and cannot be used in positions difficult of access, such as the inner portions of a built-up member.

Some time ago the writer read a paper before the Canadian Society of Civil Engineers [3] in which he described investigations of the distribution of stress in certain members made with a simplified form of Martens' mirror extensometer constructed in the laboratories of McGill University, Montreal. This instrument, extremely simple in construction and operation, was shown to be capable, when certain precautions are observed in its use, of measuring strains accurately to $\frac{1}{100,000}$ inch on a length as small as 2 inches, and of being used in the most confined positions, such, for example, as the space between two angles placed back to back and separated by as little as 3/8 inch. It was thus proved to be eminently suitable for the laboratory investigation of strain distribution in built-up members.

In the paper cited above, the distribution of stress in single- and double-angle tension members riveted to end plates was considered. It was shown that the assumption of planar distribution of stress over the cross-section was justified and that the actual distribution in a single-angle member was closely in accordance with that given by the theory of eccentric stresses developed by Bach, Müller-Breslau and others, and put into workable form by Professor L. J. Johnson, of Harvard.[4] It was also shown that a double-angle member did not act as one piece, but that each angle bent about its own neutral axis, and thus the correct way of considering a built-up member was not to regard it as a single piece bending as a beam, but as several pieces, each trying to bend about its own neutral axis, but restrained by the subsidiary members, such as tie plates or latticing.

In these experiments 3 inch × 3 inch × 1/4 inch angles were used, riveted to end plates of the same width, that being the greatest which would fit into the grips of the testing machine. In this case the effect of the end constraints was found to be very little in the case of the single angle, but it was thought advisable to repeat the experiments with end plates more like the gusset plates to which such members are usually attached in practice. To this end special grips were made so that plates of considerable size could be used, and the results of the experiments to be described later show that there must be considerable end restraint under practical conditions. In the present paper the effect of this constraint is considered, and also the effect of changing the axis of pull on the gusset plate, but the chief object is the investigation of the effect of lock angles at the ends of the members. In practice the ends of single- and double-angle members are usually secured to the gusset plates directly by a row of rivets between the plate and the angle and indirectly through the medium of a small angle riveted both to the gusset plate and to the member as shown in Fig. 5, which represents the experimental specimens. The function of this small angle, called a "lock" or "lug" angle, is supposed to be two-fold. First, by transmitting a pull through both legs of the angle or angles forming the member, it is supposed to lessen the eccentricity of connection, so that often the stress is calculated as though uniformly distributed over the cross-section; secondly, by allowing more rivets to be used at the ends of the member, it is supposed to be equivalent to lengthening the end connections. The writer hopes to show that both of these claims are to a large extent unfounded; that lock angles really serve very little useful purpose, and that the slight effect which they have, helpful or otherwise, cannot be predetermined.

---

[3] *Transactions Canadian Society of Civil Engineers,* vol. xxvi, p. 224.

[4] See *Trans. Am. Soc. Civ. Eng.,* 1906, p. 169.

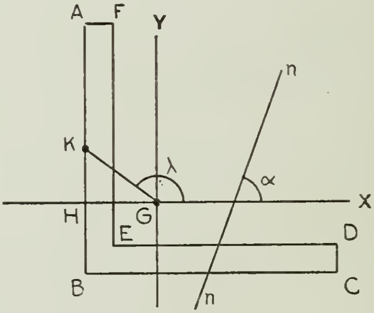
Before entering upon a discussion of the experiments a brief account of the theory upon which the analysis of the results is based will be given.

PART I.—THEORETICAL.

§1. *The Distribution of Stress in Eccentrically Loaded Members of Uniform Cross-section.*

A single angle such as is shown in Fig. 5, loaded in tension or compression through rivets in one leg, is an example of an eccentrically loaded member in which the load axis does not lie in an axis of symmetry of the cross-section. If the ends of the member are not appreciably restrained from bending by the end connections, the axis of loading may be said to lie along the line of rivets and at the common face of the end plate and the angle. This axis is represented by K in Fig. 1, which represents a cross-section of the member. It will readily be seen that the ordinary theory of eccentric loading, which is true only for loads applied in an axis of symmetry of the cross-section, cannot be applied to this case, and recourse must be had to the general theory already mentioned.[5] For a full account of this theory the reader is referred to the paper by Professor L. J. Johnson referred to above or to Appendix I of the paper by the present writer in the *Transactions of the Canadian Society of Civil Engineers,* vol. xxvi, p. 224. A brief *résumé* of the theory will be given here, as it is essential to the understanding of the experimental results. Referring to Fig. 1, let G represent the centroid of the cross-section and Gx and Gy be a pair of coordinate axes parallel to the legs of the angle. Then, if N be the normal force applied at K, the stress at any point of the cross-section will be equal to $\frac{N}{A}$, where A is the area of the section, together with a stress arising from the bending moment $N.KG$ to which the angle is subjected. This moment will cause bending about a neutral axis nn, which will not, as in the case of loading in a plane of symmetry, be perpendicular to KG, but at an angle α to Gx, given by the equation

FIG. 1.



$$\tan \alpha = \frac{I_x - J \tan \lambda}{J - I_y \tan \lambda} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

---

[5] L. J. Johnson, *loc. cit.*

where I_x and I_y are the moments of inertia of the section about Gx and Gy respectively and J is the product of inertia of the section with respect to the axes Gx and Gy,—*i.e.*, the $\int\int xydxdy$ with respect to these axes.[6] The above equation is deduced by equating the sum of the moments of the stresses over the section about Gx and Gy respectively to the components of the bending moment $N.KG$ about these axes, assuming that the distribution of stress over the section follows a linear law.[7] The stress at any point (xy) of the section may be shown to be given by either of the equations

$$f = N\left[\frac{1}{A} + \frac{y - x\tan\alpha}{J - I_y\tan\alpha}\cdot x_k\right] \dots\dots\dots\dots\dots\dots (2)$$

$$= N\left[\frac{1}{A} + \frac{y - x\tan\alpha}{I_x - J\tan\alpha}\cdot y_k\right] \dots\dots\dots\dots\dots\dots (3)$$

where (x_k, y_k) are the coördinates of the load axis K. In order to find the maximum stress, it is only necessary to substitute for (xy) the coördinates of the point most distant from the neutral axis. If f be equated to zero in either of the equations (2) or (3), the equation of the neutral axis nn will be obtained.

§2. *The S-Polygon.*

The S-polygon, a modification of the W-Fläche of Land, was first introduced by L. J. Johnson.[8] It is a figure which gives at a glance the point of maximum bending stress and the value of the latter for any given load axis, and, as its use will facilitate certain deductions to be made later, its construction will be considered briefly here.

For the bending of ordinary I sections the steel handbooks give a quantity called the "modulus" of the section which is equal to $\frac{M}{f} = \frac{I}{y}$ where M is the bending moment applied to the section, y the distance of the skin from the neutral axis, f the maximum stress and I the moment of inertia of the section about the neutral axis. It may be defined as that quantity by which the bending moment at any section must be divided in order to give the maximum stress at the section. In the general case of flexure as considered above there will be a similar quantity which may be termed the "flexure modulus" (S) of the section. Thus $S = \frac{M}{f}$. The bending moment on the section is $N.KG$. The stress due to this at any point of the section is, from equation (2), given by

---

[6] I_x and I_y are given in the steel handbooks for all ordinary sections, but J has to be calculated. For the method of calculation see either of the papers cited above.

[7] This was shown to be the case experimentally by the writer, *loc. cit.*

[8] *Loc. cit.*

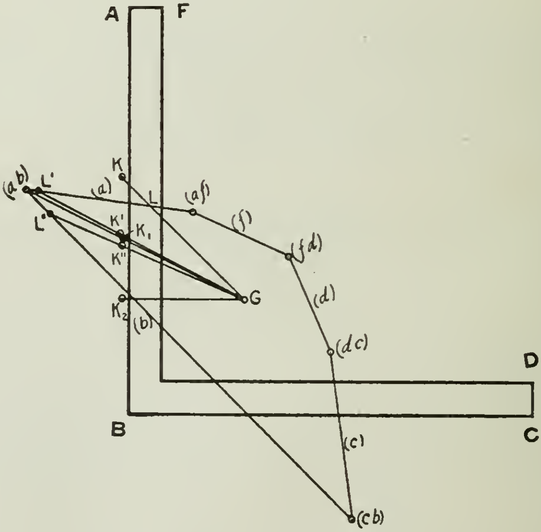
$$f_b = \frac{y - x \tan \alpha}{J - I_y \tan \alpha} \cdot NG \cos \lambda\ .\ \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Eliminating α between this equation and equation (1), and rearranging terms, the section modulus for (xy) is given by

$$S = \frac{M}{f} = \frac{I_x I_y - J^2}{(yI_y - xJ) \sin \lambda + (xI_x - yJ) \cos \lambda} \ \ldots\ldots\ldots\ldots (5)$$

If the point (xy) remains fixed while λ changes, the above is readily seen to be the polar equation of a straight line, having

FIG. 2.



radius vector S and angle λ. This line may be termed the S-line for the point (xy). If S-lines be drawn for all points at which the maximum stress may occur, a polygon, called the S-polygon, will be obtained. Thus, for example, in the case of the single angle Fig. 2, the maximum stress may occur at A, B, C, D, or F. If G be chosen as the pole and Gx as the initial line, the figure (ab), (bc), (cd), etc., is the S-polygon drawn with S to the same scale as the linear dimensions of the figure. Thus for the load point K, GL represents S and the maximum stress occurs at B. But $S = \frac{M}{f_b}$ and $M = N.KG$, therefore f_b, the bending stress at B, is equal to

$$\frac{M}{S} = N \cdot \frac{KG}{LG} \cdot$$

Thus the total stress at B, which is the maximum stress at the section, is given by

$$f = \frac{N}{A} + N \cdot \frac{KG}{LG} \cdot \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

In order that this may be true, it is, of course, necessary that the scale of the S-polygon should be the same as the linear scale of the figure and that the origin be G and the initial line Gx.

§3. *The Construction of the S-Polygon.*

The best method of constructing the S-polygon of an angle is by locating the apices. Each apex corresponds to a side. It may be shown by transforming equation (5) into rectilinear coördinates, substituting the coördinates of any two points $(x_a\ y_a)$, $(x_b\ y_b)$, and solving for the apex (ab) of the S-polygon, that

$$\left.\begin{aligned} x_{ab} &= \frac{(x_a - x_b)\,J - (y_a - y_b)\,I_y}{x_a y_b - x_b y_a}, \\ y_{ab} &= \frac{(x_a - x_b)\,I_x - (y_a - y_b)\,J}{x_a y_b - x_b y_a}. \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots (7)$$

If the side considered be parallel to Gx, so that $y_a = y_b$, the above equation gives

$$x_{ab} = \frac{J}{y_a}, \quad y_{ab} = \frac{I_x}{y_a},$$

while, if the side be parallel to Gy,

$$x_{ab} = \frac{I_y}{x_a}, \quad y_{ab} = \frac{J}{x_a}.$$

Considering, for example, the single-angle specimen I, used in the experiments to be described later and for which $I_x = I_y = 1.37$ (in.)^4, $J = -0.81$, and the distance from the centroid to the back of the angle is 0.85″, the apex of the S-polygon corresponding to the side AB has the coördinates

$$x_{ab} = -\frac{1.37}{0.85} = -1.61, \qquad y_{ab} = \frac{0.81}{0.85} = 0.95.$$

The other apices may be determined in a similar manner, and the complete polygon is shown in Fig. 2.

The S-polygon furnishes the simplest method of determining the ratio of maximum to mean stress when a number of load axes have to be considered. It may also be used to establish a number of interesting results. For instance, as the point K moves down AB, starting from A, the radius vector GL terminates first on the f line, then on the a line, and finally on the b line, showing that the point of maximum stress changes from F to A and then to B. The ratio $\frac{GK}{GL}$ also changes considerably. It will be shown later that the S-polygon is of material aid in analyzing the probable effect of a lock angle or a change in the restraining couple.

§4. *The Effect of Lateral Deflection and of End Restraints.*

The earlier experiments of the writer have shown that in the case of a single angle loaded in tension and not effectively restrained at the ends, the axis K is along the line of rivets and slightly within the loading plate. In a long member there will be a measurable lateral deflection as the load is applied, the centroid of each section trying to set itself in the load axis. This will cause a change in the position of K relative to the section and consequently affect the distribution of stress over the section. This effect is not usually great enough to be of much practical importance, but must be considered in reducing experimental results. Of much greater interest is the effect of the gusset plate and lock angle in affecting the position of the load axis. A stiff end connection will introduce constraining couples both in and at right angles to the plane of the end plate, and these may have important effects upon the distribution of stress. A lock angle is often supposed to so constrain the ends that the eccentricity of pull may be neglected, although how far this is from actually being the case will be shown later. The chief object of the present paper is the investigation of these different constraints in the case of single- and double-angle members.

§5. *The Working Loads upon Eccentrically Loaded Members.*

In a compression member it is, of course, always unsafe to allow the stress at any point to exceed the elastic limit of the material, even though the load which would cause this stress be well within the theoretical buckling load for a long column. Experiment has shown, however, that, in the case of a tension member, a redistribution of stress usually occurs under such conditions, and that the elastic limit may be considerably exceeded at certain parts of the section without danger to the structure as a whole. This would lead to the supposition that, when the stresses arising from eccentricity are taken into account, higher working stresses than usual might be used. It would, however, be unsafe to proceed on this assumption without more experimental evidence as to whether, in such case, the new distribution of stress persists without alteration after many reloadings. At present it would seem to be unwise to allow the stress over any considerable part of the structure to rise above the ordinary working stress of the material at any point of the cross-section, especially considering that there are always higher stresses locally near to the end connections. Thus it would appear that single-angle members, and to some extent double-angle members, should always be designed for the maximum stress, allowing for eccentricity,—*i.e.*, including what are often termed "secondary" stresses, although they are frequently quite as large as, or even larger than, the so-called "primary" or uniform stress, leaving what may be termed the "tertiary" or local stresses due to the end connections to be included in the factor of safety.

PART II.—THE EXPERIMENTS.

§1. *The Extensometers.*[9]

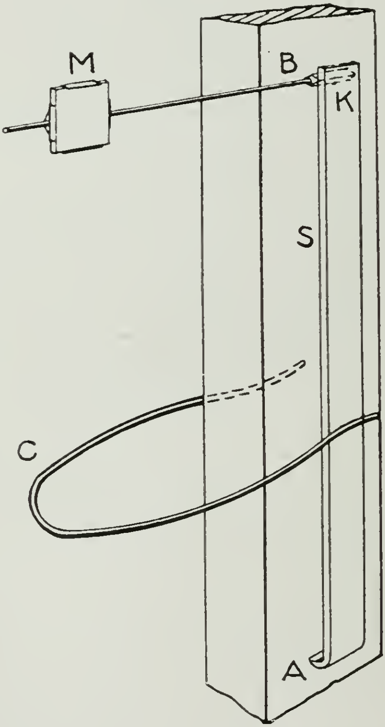
The extensometers used were a simplified form of the Martens' type, designed and constructed in the McGill Testing Laboratory, where they have been in use since 1906, and have been proved capable of giving very accurate results.

The principle of the instrument is shown in Fig. 3. It consists essentially of a double knife-edge, *K*, which fits between the specimen under test and a V groove in one end of a steel strip *S*, which is in contact with the specimen at *A*, and is pressed against it by means of a clip *C*. A change in the length of the specimen between *A* and *B* causes the knife-edge to tilt, and the tilt is measured by means of a telescope and scale, the scale being reflected in a mirror *M* attached to the knife-edge. In the actual instrument the steel strip is 3/8 inch wide, 1/8 inch thick, the length *A B* being chosen to suit requirements. The end *A* is turned at right angles and brought to a sharp edge so that it may not slip on the specimen. The knife-edge is of hardened steel about 0.18 inch × 0.12 inch × 0.45 inch, and the mirror is attached by means of a piece of steel knitting needle. The mirror is held in a clip of thin sheet steel which is arranged so that it can slide and rotate on the needle, a thin copper strip protecting its back from injury. This clip permits of a small amount of lateral adjustment. The mirror is about ½ inch square and must be as truly plane as possible, as otherwise there will be an error introduced when the image of the scale moves to a different part of its surface, as it must do if the specimen deflects at all during test. In the original form of Martens' extensometer, there was a device for adjusting the mirror and also a balance weight at the opposite side of the knife-edge, but these refinements are not only unnecessary but cumbersome, and make the instrument less adapted to use in restricted positions.

---

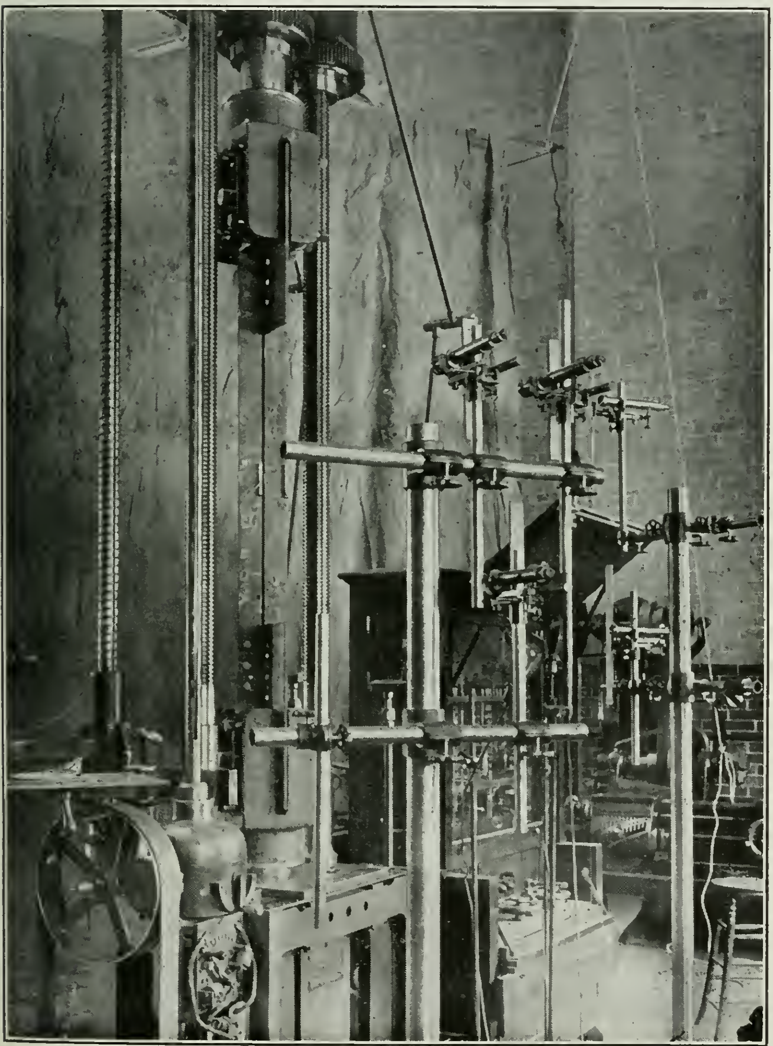
[9] This section is reprinted from the writer's earlier paper, *loc. cit.*

FIG. 3.



The extensometer is calibrated in a Whitworth measuring machine, and a calibrating rod is prepared for each instrument, giving the distance from the scale to the mirror, so that a definite distance on the scale may correspond to a given extension or compression on the specimen. In the case of the experiments described below, ½ inch on the scale, subdivided into ten equal

FIG. 4.



divisions, corresponded to $\frac{1}{1000}$ inch, so that the change of length of the specimens was easily read to $\frac{1}{100,000}$ inch. The length of the rod was about 4 feet, varying with different instruments. The angle turned through by the mirror in any test is so small that there is no appreciable error in using a straight scale for the readings. This was verified by turning the mirror in the Whitworth measuring machine through much greater angles than those through which it turns in the tests. It was also found that different strips (S) did not affect the calibration, so that a knife-edge could be used with different lengths of strip without recalibration. It was estimated that, under the conditions of test, the instrument reads accurately to $\frac{1}{100,000}$ inch.

The kind of telescope used affects greatly the facility with which readings may be taken. The McGill Testing Laboratory telescopes are adjustable vertically and horizontally, besides moving bodily about a vertical axis. They are carried on specially-made stands permitting any kind of adjustment to be made with ease (see Fig. 4). The extensometer must be carefully used in order to give correct results. The mirror should be, in its mean position, parallel to the scale and the telescope should be opposite to the mirror. The clip must be arranged so that the knife-edge is held quite firmly, otherwise it will not tilt correctly. The best clips are made from pieces of copper wire.

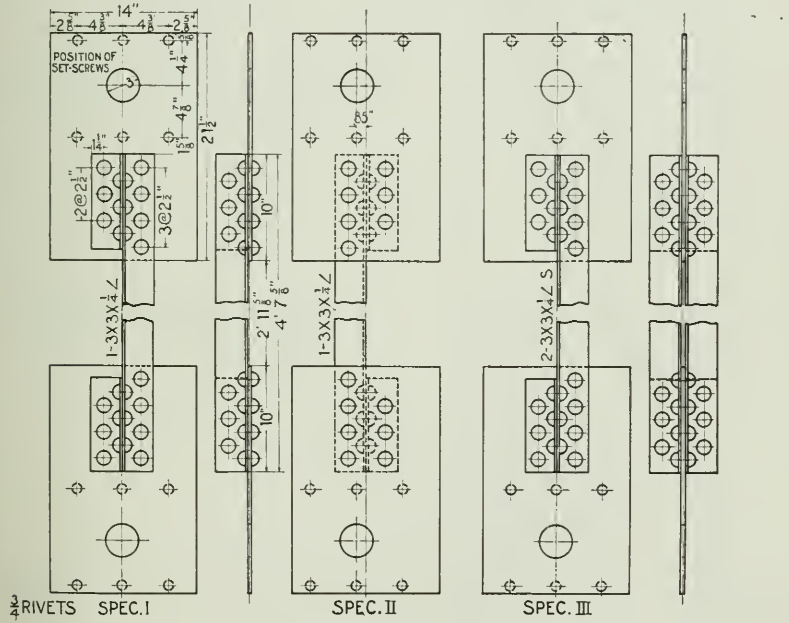
If the direction of $A\ B$ remains unchanged during test, the difference of the scale reading between two loads will be an accurate measure of the strain of $A\ B$ for the given load difference, but if $A\ B$ alters in direction this will not be the case. If, however, two readings are taken, one with the extensometer in the position shown, and the other with the knife-edge at A and the sharp edge of the strip at B, the mean of the two will be correct. When any doubt exists it is always better to do this so as to eliminate possible error.

In the opinion of all who have worked with these instruments at McGill University they are the most simple, practicable, and accurate extensometers in use. It will be seen that they may be readily used in the most restricted positions, as, for instance, between the two angles of the double-angle members, where the width is only ⅜ inch. Fig. 4 shows the general arrangement of the apparatus.

§2. *The Specimens and the Method of Holding Them.*

Experiments were made on the three specimens, two single-angle members and one double-angle, shown in Fig. 5. All were ordinary shop products made by the Dominion Bridge Company of Montreal, and the angles were of uniform section 3 inches × 3 inches × ¼ inch. Careful measurements showed that the section varied a little in the three specimens, and the actual areas, moments of inertia, etc., were computed and are given at the heads of Tables I, II, and III, pp. 153–155. The members were of a uniform length of 55⅝ inches over all and 35⅝ inches between the end plates, and were secured to the latter by means of four ¾-inch rivets having a pitch of 2½ inches and by lock angles riveted to the plate by three ¾-inch rivets and to the outstanding leg of the angle by a like number.

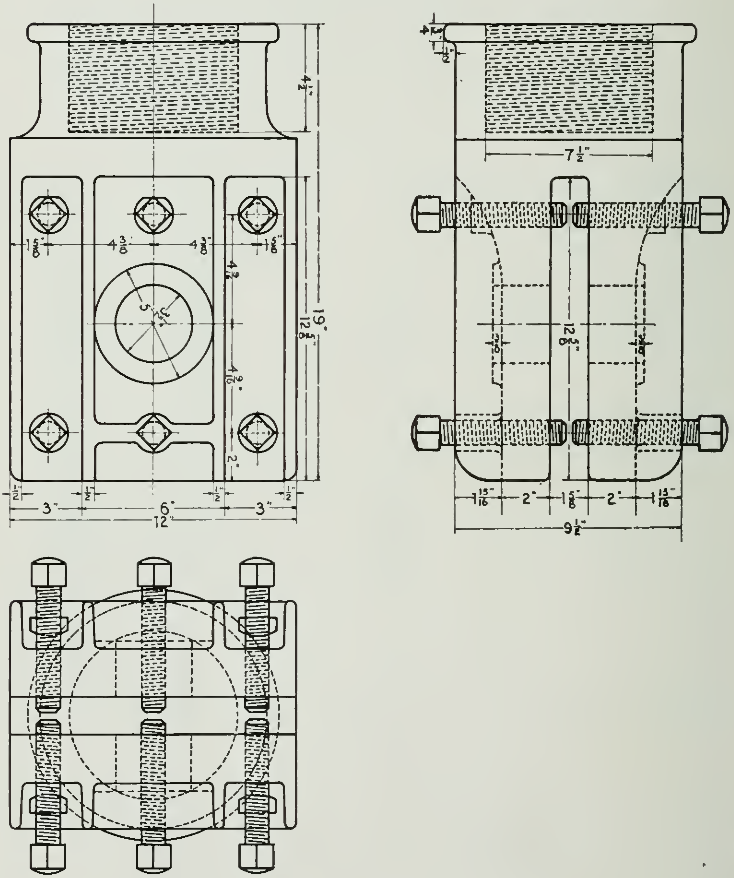
FIG. 5.



Specimens used in the experiments.

In the earlier experiments referred to above, similar angles were used, without lock angles, riveted to end plates of the same width, 3 inches, as the angles, secured directly in the grips of the testing machine, the distance from the end of the grips to the end of the angle being about 5½ inches. With these end plates it was found that the restraining couple upon the angle was very small, and it was thought desirable, in the present tests, to substitute end connections more nearly similar to those met with in practice,

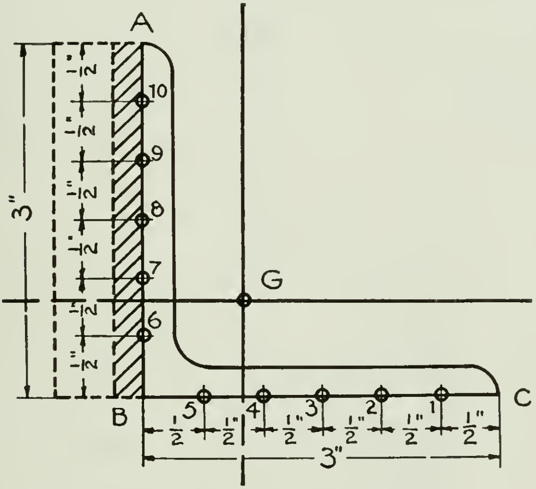
FIG. 6.



i.e., wide plates firmly secured. To this end special grips were designed to fit on the jaws of the machine. These are shown in Fig. 6. They were steel castings. The end plates, which were 1 foot 2 inches wide and ⅜ inch thick, were held by steel pins 3 inches in diameter fitting tightly into bushes in the castings, and were restrained from turning by six set screws on each side, as indicated in Fig. 6. The distance from the end of the angle to the set screws was approximately 2 inches, so that the ends of the members were quite as effectively held as in most practical cases.

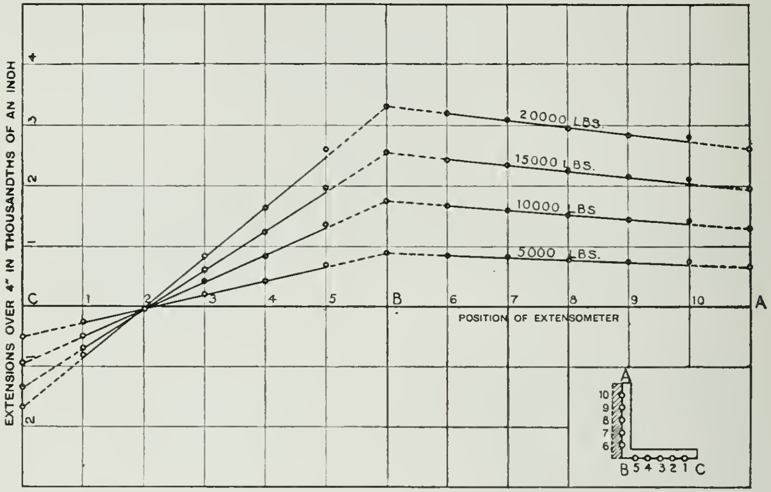
The position of the pin with respect to the rivets was made different in the different specimens. In Specimens I and III it was in line with the back of the main angle, while in Specimen II it was in line with the centroid of the main angle. The object of this was to find the effect of a change in the line of pull on the gusset plate,— *i.e.*, of different eccentricity of end connection. Further changes were also made during the tests, as will be described later. The specimens were also tested with the lock angles removed in order to study the action of the latter.

FIG. 7.



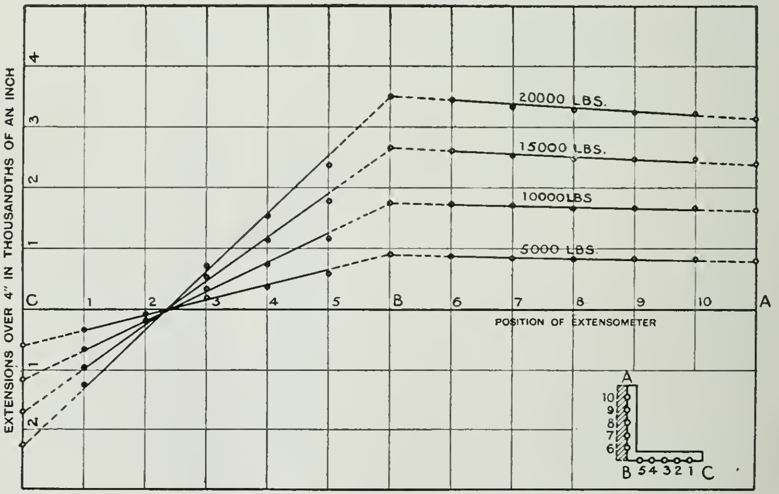
The machine used was the Emery testing machine in the Testing Laboratory of McGill University. This machine is of the vertical type and has a capacity of 150,000 pounds. It is eminently suited to this kind of work as the line of pull, suitable means being taken to steady the straining head, remains constant, and there is an entire absence of vibration.

FIG. 8.



Specimen I with lock angle. Central section.

FIG. 9.

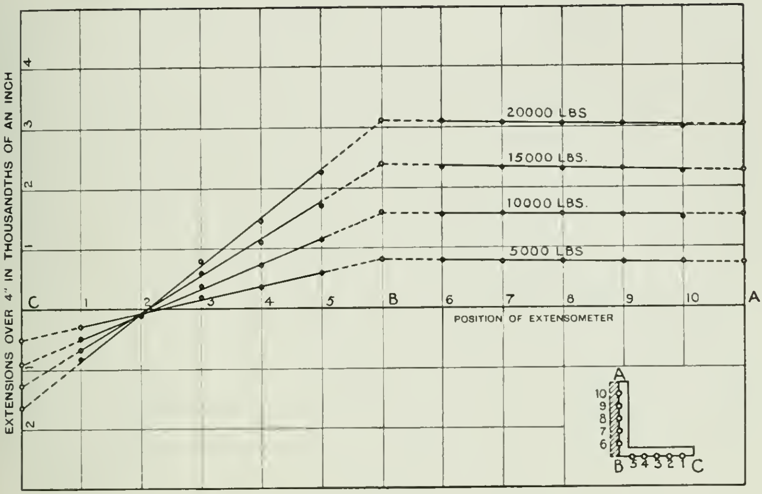


Specimen I with lock angle. End section.

§3. *The Tests.*

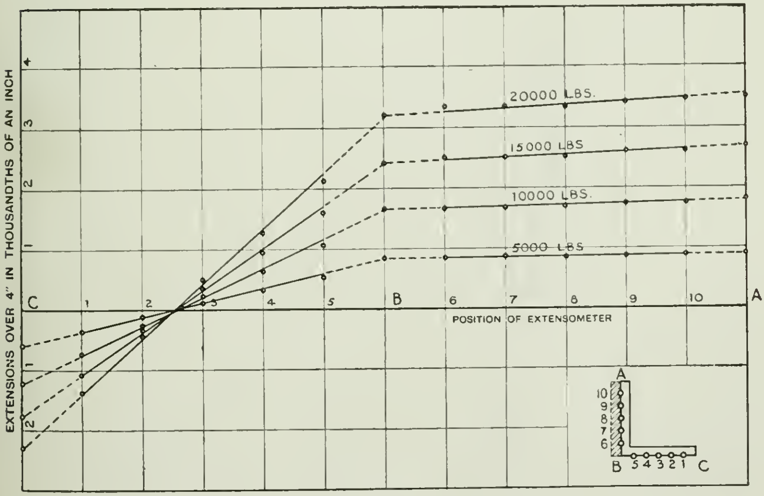
The experiments were directed to a determination of the distribution of stress under different loads at the central cross-sections of the specimens and also at sections near to the end plates.

FIG. 10.



Specimen I. Lock angle removed. Central section.

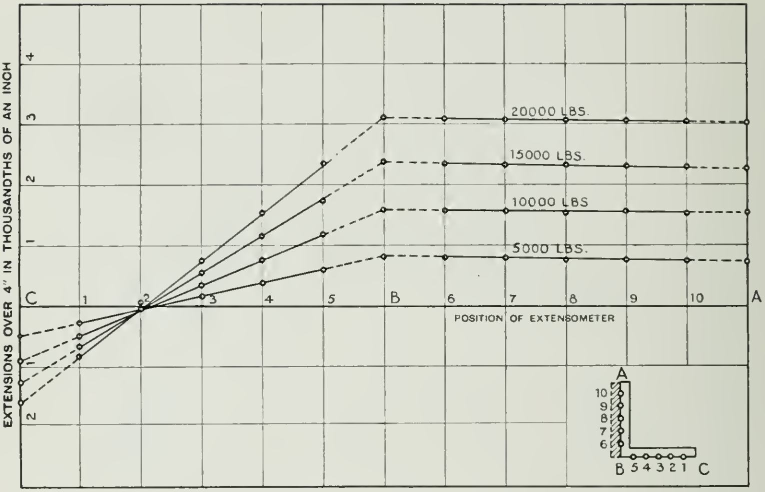
FIG. 11.



Specimen I. Lock angle removed. End section.

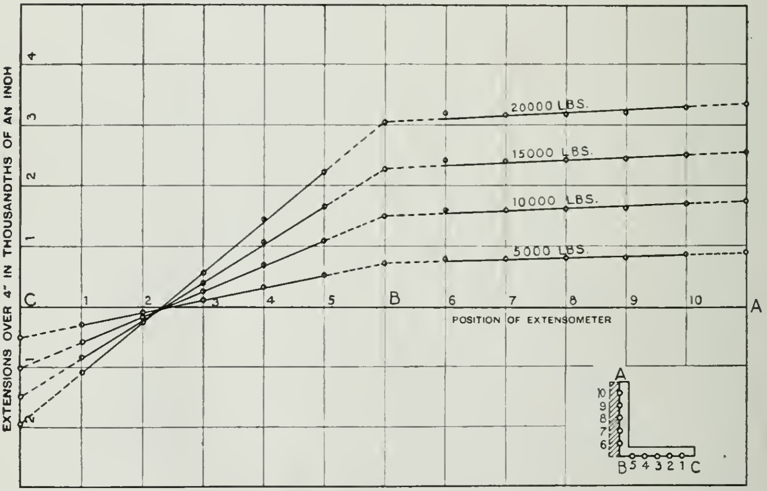
To this end extensometers were used at these sections with their distance pieces set parallel to the axis of pull. From the readings of these the longitudinal strains were found, and these were

FIG. 12.



Specimen II. With lock angle. End section.

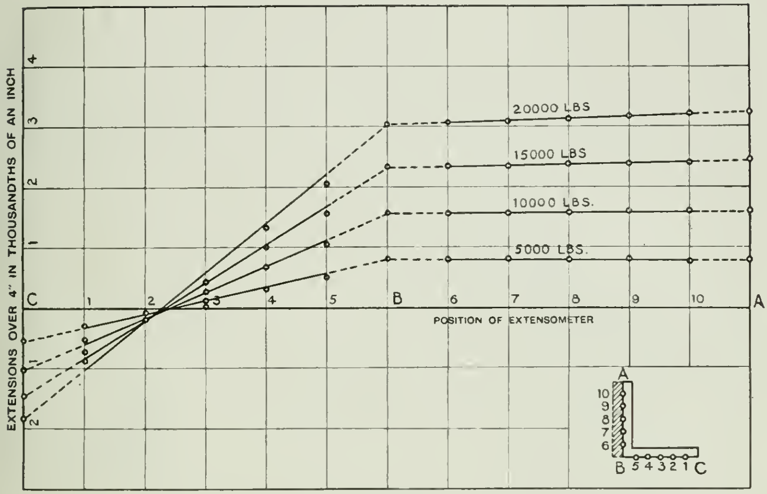
FIG. 13.



Specimen II with lock angle. End section.

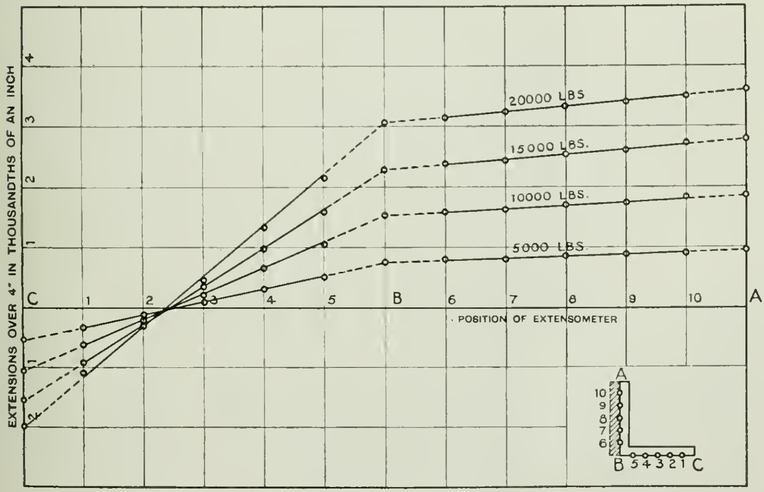
taken as being proportional to the longitudinal stresses, the effect of the strains perpendicular to the axis being so small as to be negligible. The distance pieces of the extensometers were 4

FIG. 14.



Specimen II. Lock angle removed. Central station.

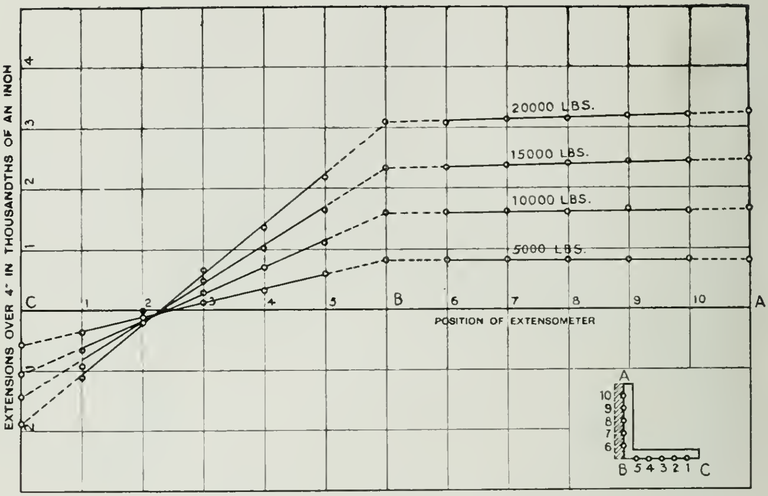
FIG. 15.



Specimen II. Lock angle removed. End section.

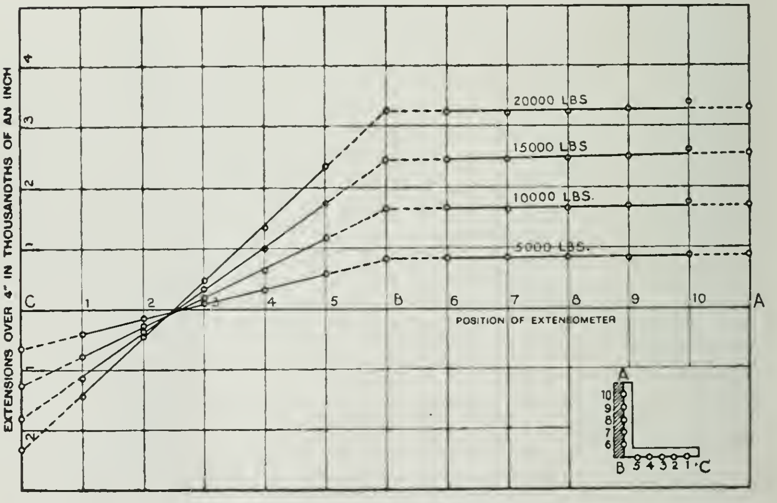
inches long, so that the strains measured were mean strains over that length. They could be considered as giving the distribution of stress over the central cross-section of the 4-inch range without

FIG. 16.



Specimen II Line of pull in line of rivets. Central section.

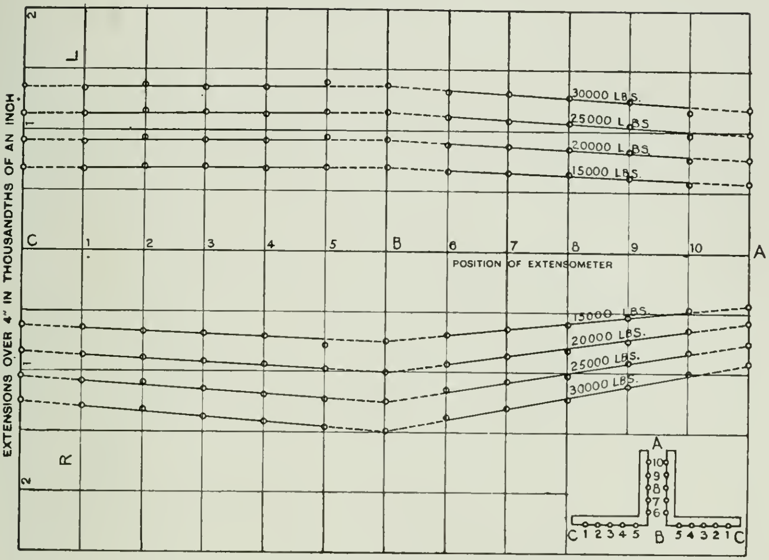
FIG. 17.



Specimen II. Line of pull in line of rivets. End section.

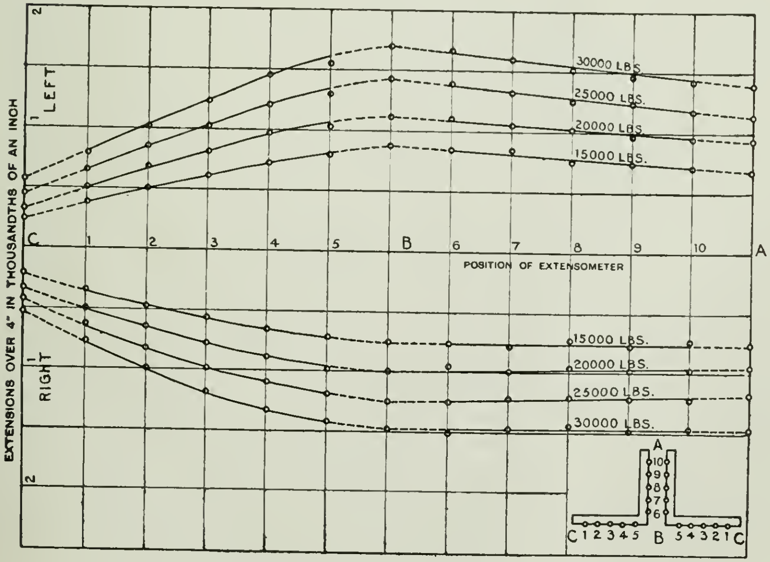
error at the central section, and to a fair degree of approximation at the ends. Readings of the extensometers were taken at half-inch intervals over the outside face of the angles, as shown in

FIG. 18.



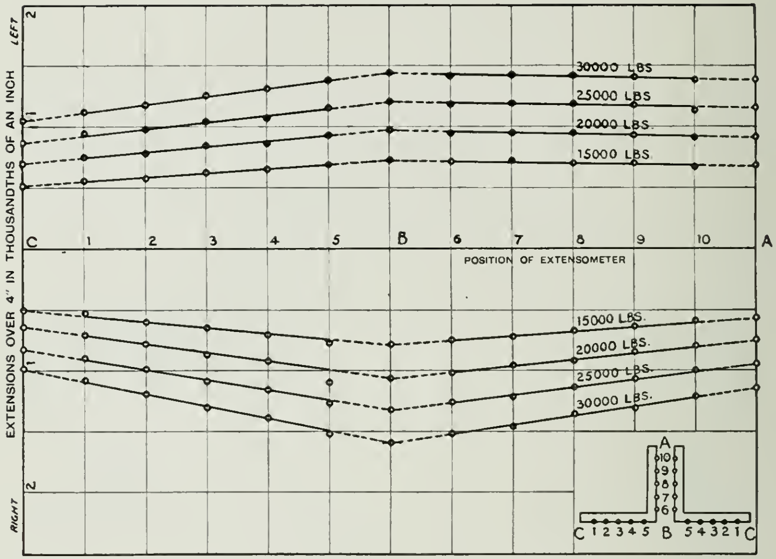
Double angle. Central station.

FIG. 19.



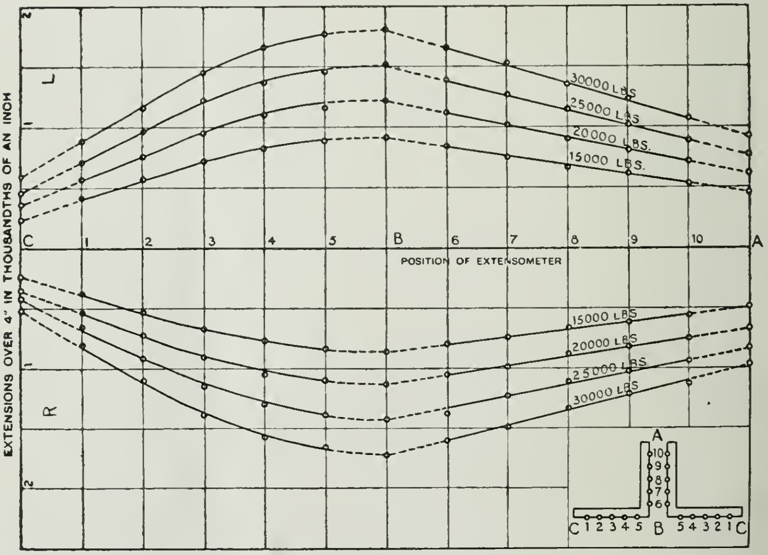
Double angle. End section.

FIG. 20.



Double angle without lock angles. Central section.

FIG. 21.



Double angle. Lock angles removed. End section.

Fig. 7, the extensometers being arranged first with the mirror at the lower end and then at the upper end and the mean of these readings taken, so that errors due to bending of the specimen were eliminated, as described above.

All the tests were carried out in a uniform manner. Two or more extensometers being set in position, an initial load of 100 pounds was applied to the specimen; the load was increased to its maximum value several times and then brought back to its initial value. The zeros of the extensometers were then set and readings taken at 5000, 10,000, 15,000, and 20,000 pounds respectively in the case of the single-angles and 15,000, 20,000, 25,000, and 30,000 pounds respectively in the case of the double-angle. The load was then brought back to its initial value and the zeros of the extensometers checked. No sets were allowed to pass in which the extensometers failed to return to their initial readings. All observations were repeated at least once before the extensometers were removed to other positions.

The uniformity of the results was remarkable. It was found that the specimen could be taken out of the machine and replaced without the extensometer readings for a given load being appreciably altered.

The lateral deflections of the specimens were carefully measured by means of telescopes and scales reading to $\frac{1}{100}$ inch. These deflections were allowed for in reducing the results, as will be explained later.

The Emery machine was calibrated by levers during the period of the tests and was found to be reading correctly to within 1 per cent. at all loads.

The sequence of tests was as follows:

(1) Specimen I.—Single, 3 inches × 3 inches × ¼ inch angle with lock angle. Line of pull on end plate in line with back of main angle.

(2) Same specimen, with lock angle removed.

(3) Specimen II.—Single, 3 inches × 3 inches × ¼ inch angle with lock angle. Line of pull on end plate in line with centroid of main section.

(4) Same specimen with lock angle removed.

(5) Same specimen with line of pull on end plate changed so as to be in line with rivets.

(6) Specimen III.—Double, 3 inches × 3 inches × ¼ inch angle section, space of ⅜ inch between angles, with lock angles. Line of pull in line with unconnected legs of main angles.

(7) Same specimen with lock angles removed.

The stresses corresponding to the extensometer readings are given in Tables I to III, pp. 153–155, the values of E being calculated from the readings and the total load, as will be described later. The curves of stress distribution are shown in Figs. 8 to 21.

PART III.—ANALYSIS OF THE EXPERIMENTAL RESULTS.

§1. *The Planar Distribution of Stress.*

The theory described in Part I of this paper is based upon the assumption that the distribution of stress over a cross-section normal to the axis of load follows a linear law. That this is true for members of the type considered in this paper has already been shown by the writer.[10] It is also evident from the curves shown in Figs. 8 to 21. These represent the actual mean extensometer readings for the various cases, the mean straight line through the experimental points being drawn and continued so as to give the maximum strains, which occur at one or other of the corners of the angles. It will be noticed that in every case the mean straight lines for readings 1 to 5, on being produced to the corner of the angle, agree exactly with those for readings 6 to 10. The deviations of the experimental points from the straight lines are in nearly all cases so small as to be unimportant, especially considering that the specimens were ordinary shop products. Where deviations do occur they are usually regular and apparently denote a slight actual departure from planar distribution. They are most marked at the end sections and are probably due to warping produced by the end constraints. In one case only do they become important,—*i.e.,* at the end of the double-angle specimen (Figs. 19 and 21). For this section the mean straight lines could not be drawn and the results have not been reduced. These deviations, however, entirely vanish at the central section of the same specimen, and are thus probably due to the great end constraints in this case.

---

[10] *Loc. cit.*

§2. *The Method of Analysis.*

The planar distribution of stress having been established, the equations of Part I may be applied to determine the position of the load axis at each section. The details of this analysis are given in Table IV. The method, being the same for all cases, may be illustrated by a single example. Consider the central section of Specimen I with lock angle at 20,000 pounds load. The distribution of strain is shown in Fig. 8, and the constants for the section are given at the head of Table I. The results of the calculation are given in the first line of Table IV. Lines through the centroid of the section parallel to the legs of the angle being taken as coördinate axes, the point of zero stress in the angle is seen to have coördinates $(1.15, -0.85)$. This is one point on the neutral axis. Another may be found by calculating where the $6-10$ line would cut the x-axis if produced. Thus the neutral axis is found to be inclined to the x-axis at an angle of $\tan^{-1} - 6.93$. This is $\tan\alpha$ in the notation of Part I. Substituting this value, the

TABLE I.

Stresses Corresponding to the Mean Extensometer Readings for Specimen I.

Constants.—Area of cross-section, 1.60 square inches.
Distance from centroid to back of angle, 0.85 inch.
$I = 1.37$ (inch)^4. $J = -0.81$ (inch)^4.
$E = 29.1 \times 10^6$ pounds per square inch.
Stresses in pounds per square inch. Tension +. Compression −.

	Load N. (lbs.)	1	2	3	4	5	6	7	8	9	10
(a) *With lock angle.*											
Central section	5,000	− 2,380	− 360	1,450	2,980	5,020	6,180	5,960	5,520	5,310	5,310
	10,000	− 3,420	− 440	3,060	6,040	9,810	12,140	11,560	10,980	10,450	10,310
	15,000	− 5,020	− 360	4,510	8,940	14,390	17,720	17,000	16,300	15,540	15,280
	20,000	− 5,960	− 70	6,250	11,910	18,810	23,280	22,400	21,440	20,580	20,280
Section 2½″ from end plate	5,000	− 2,470	− 510	1,310	2,620	4,220	6,400	6,250	6,110	6,110	6,110
	10,000	− 4,870	− 940	2,480	5,380	8,500	12,700	12,420	12,140	12,140	12,070
	15,000	− 7,060	−1,240	3,780	8,290	13,000	19,010	18,450	18,170	18,100	18,100
	20,000	− 9,090	−1,450	5,240	11,200	17,380	25,210	24,350	24,000	23,700	23,400
(b) *Without lock angle.*											
Central section	5,000	− 2,030	− 580	1,380	2,690	4,290	5,750	5,680	5,600	5,530	5,390
	10,000	− 3,640	− 730	2,760	5,390	8,440	11,490	11,490	11,330	11,200	10,830
	15,000	− 4,940	− 800	4,290	8,000	12,420	17,000	17,000	16,880	16,800	16,380
	20,000	− 6,030	− 730	5,810	10,690	16,420	22,470	22,400	22,240	22,240	21,780
Section 2½″ from end plate	5,000	− 2,690	− 870	650	2,260	4,290	5,750	5,670	5,600	5,520	5,380
	10,000	− 5,390	−1,960	1,530	4,510	8,440	12,160	12,220	12,380	12,720	12,720
	15,000	− 7,930	−2,620	2,470	6,840	12,420	18,180	18,270	18,320	18,920	18,990
	20,000	−10,100	−3,270	3,640	9,240	16,420	24,210	24,280	24,210	24,850	25,100

coördinates of the point of zero stress and $f = o$ in equations (2) and (3), the coördinates (x_k, y_k) of the load axis are found to be $(-0.76, 0.37)$. All the values of (x_k, y_k) given in Table IV were calculated in a similar manner. The coördinates (x_k, y_k) give the position of the load axis relative to the cross-section considered. This depends, to some extent, upon the lateral deflection of the section, so that, in order to find the position of the load axis where the load enters the angle, it is necessary to correct for this deflection. Column (4) of Table IV gives the mean deflections of the centroids of the sections under the different loads measured as described above, and column (5) gives the values of (x_k, y_k) referred to the end sections of the specimens taken as being the middle section of the riveted ends.

TABLE II.

Stresses Corresponding to the Mean Extensometer Readings for Specimen II.

Constants.—Area of cross-section, 1.49 square inches.
Distance from centroid to back of angle, 0.85 inch.
$I = 1.29$ (inch)^4. $J = -0.76$ (inch).^{4}
$E = 31.1 \times 10^6$ pounds per square inch.
Stresses in pounds per square inch. Tension +. Compression −.

	Load N. (lbs.)	1	2	3	4	5	6	7	8	9	10
(a) *With lock angle.*											
Central section	5,000	− 2,100	− 310	1,250	3,040	4,590	6,300	6,230	5,990	5,990	5,920
	10,000	− 3,890	− 310	2,650	5,920	9,180	12,380	12,300	12,070	12,070	11,980
	15,000	− 5,130	− 150	4,200	8,950	13,610	18,350	18,290	18,120	17,980	17,810
	20,000	− 6,850	+ 540	5,760	11,980	18,130	24,200	24,150	23,900	23,810	23,500
Section 2½″ from end plate	5,000	− 2,340	− 780	780	2,490	4,050	6,150	6,150	6,300	6,300	6,780
	10,000	− 4,510	−1,400	1,870	5,370	8,480	12,450	12,370	12,510	12,770	13,210
	15,000	− 6,620	−1,870	2,960	8,250	12,830	18,750	18,500	18,750	18,990	19,600
	20,000	− 8,560	−2,100	4,440	11,280	17,280	24,900	24,650	24,750	24,970	25,680
(b) *Without lock angle.*											
Central section	5,000	− 2,250	− 700	930	2,410	4,040	6,230	6,150	6,230	6,230	6,230
	10,000	− 4,050	−1,090	2,020	5,140	8,100	12,210	12,210	12,380	12,430	12,430
	15,000	− 5,600	−1,320	3,270	7,860	12,100	18,220	18,290	18,430	18,600	18,680
	20,000	− 6,920	−1,320	4,590	10,500	15,880	23,800	24,100	24,280	24,680	24,820
Section 2½″ from end plate	5,000	− 2,410	− 860	700	2,410	3,970	6,150	6,230	6,610	6,840	7,000
	10,000	− 4,590	−1,550	1,550	5,060	8,160	12,380	12,780	13,080	13,540	14,220
	15,000	− 6,620	−2,100	2,570	7,780	12,420	18,600	18,980	19,600	20,500	21,170
	20,000	− 8,490	−2,410	3,660	10,420	16,720	24,600	25,100	25,900	26,440	27,700
(c) *Load axis on gusset plate changed to line of rivets.*											
Central section	5,000	− 2,880	− 780	1,010	2,490	4,360	6,300	6,300	6,300	6,300	6,300
	10,000	− 5,290	−1,400	2,260	5,290	8,640	12,450	12,480	12,480	12,680	12,480
	15,000	− 7,160	−1,630	3,660	7,860	12,820	18,290	18,420	18,590	18,810	18,810
	20,000	− 8,710	−1,550	5,130	10,670	16,950	23,800	24,250	24,420	24,800	24,980
Section 2½″ from end plate	5,000	− 3,190	−1,170	620	2,410	4,510	6,460	6,460	6,530	6,530	6,850
	10,000	− 6,230	−2,180	1,480	5,060	9,100	12,900	12,730	12,900	13,130	13,600
	15,000	− 8.950	−2,880	2,640	7,780	13,520	19,120	19,050	19,210	19,520	20,300
	20,000	−11,280	−3,500	3,680	10,420	18,280	25,200	25,120	25,280	25,750	26,420

The value of E for each specimen may also be found from the experimental results. In the case considered above the ratio of maximum to mean stress for the calculated position of the load axis computed from equation (2) is 1.945 [11] The elongation due

TABLE III.

Stresses Corresponding to the Mean Extensometer Readings for Specimen III (Double-angle).

Constants (Each angle).—Area of cross-section, 1.54 square inches.
Distance from centroid to back of angle, 0.85 inch.
$I = 1.33$ (inch).^{4} $J = -0.78$ (inch).^{4}
$E = 30.1 \times 10^6$ pounds per square inch.
Stresses in pounds per square inch. Tension +. Compression −.

	Load N. (lbs.)	1	2	3	4	5	6	7	8	9	10
(a) *With lock angle.*											
Central section, left.	15,000	5,040	5,190	5,190	5,110	5,190	4,960	4,890	4,810	4,590	4,210
	20,000	6,700	6,920	6,850	6,850	7,070	6,620	6,550	6,400	6,250	5,710
	25,000	8,440	8,660	8,580	8,500	8,660	8,360	8,130	7,980	7,830	7,220
	30,000	10,080	10,300	10,170	10,170	10,470	9,930	9,860	9,640	9,410	8,730
Central section, right.	15,000	4,890	5,040	5,190	5,270	5,490	5,190	4,820	4,510	4,060	3,610
	20,000	6,630	6,700	6,930	7,080	7,310	7,000	6,470	6,160	5,560	4890
	25,000	8,210	8,290	8,660	8,960	9,260	8,650	8,130	7,750	6,920	6,240
	30,000	9,800	9,940	10,380	10,690	10,990	10,380	9,770	9,250	8,350	7,520
Section 2½″ from end plate, left.	15,000	2,860	3,690	4,580	5,410	5,940	6,310	6,310	5,650	5,560	5,260
	20,000	3,760	5,110	6,090	7,300	7,680	8,280	7,900	7,670	7,230	7,070
	25,000	4,890	6,390	7,680	9,030	9,710	10,390	9,930	9,400	9,250	8,800
	30,000	5,940	7,600	9,250	10,900	11,580	12,490	11,970	11,370	10,900	10,600
Section 2½″ from end plate, right.	15,000	2,635	3,610	4,280	4,960	5,340	5,710	5,860	5,490	5,860	5,560
	20,000	3,760	4,890	5,860	6,690	7,300	7,150	7,450	7,220	7,370	7,300
	25,000	4,740	6,240	7,450	8,270	8,950	9,410	9,180	9,110	9,180	9,260
	30,000	5,860	7,520	8,960	10,000	10,680	11,340	11,030	10,890	11,200	11,030
(b) *Without lock angle.*											
Central section, left.	15,000	4,220	4,360	4,660	4,890	5,190	5,340	5,410	5,260	5,190	4,960
	20,000	5,650	5,850	6,320	6,470	7,000	7,070	7,150	7,070	7,000	6,760
	25,000	7,070	7,380	7,830	8,050	8,650	8,880	8,950	8,880	8,800	8,500
	30,000	8,430	8,880	9,410	9,860	10,390	10,600	10,680	10,600	10,530	10,380
Central section, right.	15,000	3,990	4,510	4,890	5,260	5,790	5,650	5,490	5,120	4,820	4,440
	20,000	5,340	6,020	6,550	6,920	8,280	7,670	7,230	6,920	6,400	6,020
	25,000	6,780	7,450	8,200	8,730	9,480	9,480	9,180	8,580	8,050	7,520
	30,000	8,130	8,950	9,790	10,430	11,410	11,420	10,990	10,220	9,860	9,180
Section 2½″ from end plate, left.	15,000	3,080	4,280	5,420	6,170	6,620	6,320	5,640	4,960	4,580	3,980
	20,000	4,290	5,720	7,150	8,280	8,730	8,420	7,680	6,770	6,090	5,340
	25,000	5,340	7,220	9,180	10,300	10,990	10,460	9,470	8,570	7,670	5,690
	30,000	6,620	8,740	10,900	12,490	13,220	12,500	11,500	10,150	9,250	7,960
Section 2½″ from end plate, right.	15,000	2,860	3,990	5,110	5,800	6,250	5,950	5,560	4,960	4,660	4,220
	20,000	3,990	5,490	6,850	7,900	8,280	7,900	7,370	6,620	6,170	5,650
	25,000	4,970	6,920	8,650	9,780	10,380	10,000	9,260	8,350	7,670	7,070
	30,000	6,100	8,280	10,440	11,890	12,490	12,030	11,200	10,090	9,180	8,500

[11] It would, of course, be incorrect to take the mean height of the plotted diagrams for a given section as being the mean extension over the section, since the curves only give the distribution of strain over the outside faces of the angles.

TABLE IV.

Reduction of Experimental Results.

Specimen and section	Load (lbs.)	1	2	3		4		5		6	7
		Inclination of neutral line	Point of zero stress y= −0.85″	Load axis referred to axes through centroid of section		Lateral deflection of centroid of section referred to mid rivet section		Load axis referred to axes through mid rivet section		Max. stress lbs. per sq. in.	Ratio of maximum to mean stress
		tan *α*	x	x_k	y_k	x	y	x_k	y_k		
		(all measured in inches)									
Specimen I. With lock angle.											
				−	+			−	+		
Central....	5,000	− 6.11	1.05	0.85	0.40	0.04	0.01	0.89	0.41	6,480	2.08
	10,000	− 5.73	1.10	0.81	0.37	0.08	0.02	0.89	0.40	12.720	2.05
	15,000	− 6.40	1.11	0.79	0.38	0.11	0.02	0.90	0.40	18,550	2.00
	20,000	− 6.93	1.15	0.76	0.37	0.15	0.03	0.91	0.40	24,080	1.94
					Mean values			0.90	0.40		
				−	+			−	+		
End.......	5,000	−15.00	0.95	0.92	0.50	0.03	0.00	0.95	0.50	6,550	2.04
	10,000	−20.95	0.95	0.92	0.51	0.05	0.01	0.97	0.52	12,720	1.98
	15,000	−16.26	0.97	0.90	0.49	0.07	0.01	0.97	0.50	19,420	1.98
	20,000	−14.81	0.97	0.90	0.49	0.09	0.02	0.99	0.51	25,540	2.00
					Mean values			0.97	0.51		
Specimen I. Without lock angle.											
				−	+			−	+		
Central....	5,000	−16.5	0.99	0.88	0.48	0.04	0.01	0.92	0.49	5,900	1.96
	10,000	−31.6	1.05	0.82	0.47	0.08	0.01	0.90	0.48	11,640	1.86
	15,000	−28.4	1.10	0.78	0.44	0.12	0.01	0.90	0.46	18,030	1.82
	20,000	−52.9	1.11	0.77	0.45	0.15	0.02	0.92	0.47	22,620	1.79
					Mean values			0.91	0.47		
				−	+			−	+		
End.......	5,000	24.30	0.87	0.97	0.60	0.03	0.00	1.00	0.60	6,480	2.04
	10,000	19.15	0.87	0.97	0.60	0.05	0.00	1.02	0.61	13,100	2.05
	15,000	15.58	0.87	0.96	0.61	0.07	0.01	1.03	0.62	19,500	2.06
	20,000	14.45	0.88	0.95	0.60	0.09	0.01	1.04	0.61	25,820	2.07
					Mean values			1.02	0.61		
Specimen II. With lock angle.											
				−	+			−	+		
Central....	5,000	−16.4	1.00	0.88	0.48	0.03	0.00	0.91	0.48	6,300	1.95
	10,000	−41,6	1.07	0.81	0.46	0.07	0.00	0.88	0.46	12,450	1.83
	15,000	−30.7	1.10	0.79	0.45	0.10	0.01	0.89	0.46	18,670	1.82
	20,000	−59.2	1.12	0.78	0.45	0.13	0.01	0.91	0.46	24,260	1.78
					Mean values			0.90	0.46		
				−	+			−	+		
End	5,000	10.6	0.90	0.93	0.61	0.02	0.00	0.95	0.60	6,920	2.08
	10,000	20.4	0.91	0.93	0.58	0.04	0.00	0.97	0.58	13,520	2.00
	15,000	23.0	0.95	0.90	0.55	0.06	0.01	0.96	0.56	19,820	1.96
	20,000	42.7	0.98	0.88	0.53	0.08	0.01	0.96	0.54	26,150	1.90
					Mean values			0.96	0.57		
Specimen II. Without lock angle.											
				−	+			−	+		
Central....	5,000	∞	0.90	0.96	0.57	0.04	0.00	1.00	0.57	6,220	1.94
	10,000	87.60	0.93	0.93	0.55	0.08	0.00	1.01	0.55	12,370	1.93
	15,000	42,20	0.98	0.88	0.53	0.12	0.01	1.00	0.54	18,650	1.90
	20,000	23.30	1.00	0.86	0.53	0.14	0.01	1.00	0.54	25,100	1.83
					Mean values			1.00	0.55		
				−	+			−	+		
End.......	5,000	7.01	0.86	0.96	0.65	0.03	0.00	0.99	0.65	7,380	2,18
	10,000	8.20	0.91	0.92	0.61	0.04	0.00	0.96	0.61	14,470	2.09
	15,000	7.94	0.92	0.91	0.60	0.06	0.01	0.97	0.61	21,600	2.09
	20,000	9.40	0.96	0.88	0.57	0.08	0.01	0.96	0.58	28,000	2.03
					Mean values			0.97	0.61		

TABLE IV—*Continued.*
Reduction of Experimental Results.

Specimen and section	Load (lbs.)	1	2	3		4		5		6	7
		Inclination of neutral line	Point oi zero stress $y = -6.85''$	Load axis referred to axes through centroid of section		Lateral deflection of centroid of section referred to mid rivet section		Load axis referred to axes through mid rivet section		Max, stress lbs. per sq. in.	Ratio of maximum to mean stress
		tan α	x	x_k	y_k	x	y	x_k	y_k		
		(all measured in inches)									
Specimen II. Load axis changed to line of rivets.											
				−	+			−	+		
Central....	5,000	∞	0.90	0.96	0.57	0.04	0.00	1.00	0.57	6,300	1.94
	10,000	53.30	0.95	0.91	0.55	0.09	0.00	1.00	0.54	12,820	1.92
	15,000	29.20	0.99	0.87	0.53	0.12	0.01	0.99	0.54	19,110	1.90
	20,000	27.35	1.02	0.84	0.52	0.15	0.01	0.99	0.52	25,260	1.89
						Mean values		1.00	0.54		
				−	+			−	+		
End.......	5,000	30.00	0.81	1.05	0.64	0.03	0.00	1.08	0.41	6,840	2.11
	10,000	58.80	0.83	1.03	0.62	0.05	0.00	1.08	0.40	13,220	2.05
	15,000	38.60	0.87	0.99	0.60	0.07	0.00	1.07	0.41	19,890	2.02
	20,000	111.30	0.90	0.96	0.57	0.10	0.00	1.06	0.40	25,740	1.96
						Mean values		1.07	0.40		
Specimen III. Double-angle with lock angles.											
				+	−						
Left angle central	15,000	− 0.15	115.0	0.02	0.05					5,270	1.06
	20,000	− 0.12	153.3	0.02	0.05	Lateral deflections negligible				6,960	1.06
	25,000	− 0.14	142.8	0.02	0.04					8,650	1.05
	30,000	− 0.15	136.6	0.02	0.04					10,340	1.05
		Mean values		0.02	0.04						
Left angle end	15,000									6,240	1.26
	20,000	Non-planar distribution of stress..................								8,320	1.26
	25,000									10,700	1.30
	30,000									12,720	1.29
				+	−						
Right angle central	15,000	− 0.39	17.90	0.03	0.11					5,640	1.19
	20,000	− 0.36	19.15	0.03	0.11	Lateral deflections negligible				7,520	1.19
	25,000	− 0.39	18.66	0.03	0.11					9.410	1.18
	30,000	− 0.40	18.75	0.02	0.10					11,200	1.18
		Mean values		0.03	0.11						
Right angle end	15,000									5,640	1.19
	20,000	Non-planar distribution of stress..................								7,520	1.19
	25,000									9,410	1.19
	30,000									11,200	1.14
Specimen III. Double-angle without lock angles.											
				−	+						
Left angle central	15,000	− 4.20	9.51	0.08	0.03					5,460	1.11
	20,000	− 4.03	9.52	0.08	0.03	Lateral deflections negligible				7,330	1.11
	25,000	− 6.61	10.05	0.08	0.04					9,030	1.10
	30,000	− 7.20	10.52	0.08	0.04					10,750	1.09
		Mean values		0.08	0.03						
Left angle end	15,000									6,810	1.39
	20,000	Non-planar distribution of stress..................								9,190	1.40
	25,000									11,360	1.38
	30,000									13,530	1.38
				−	−						
Right angle central	15,000	− 1.34	7.39	0.07	0.02					5,950	1.22
	20,000	− 1.38	6.83	0.08	0.02	Lateral deflections negligible				7,980	1.24
	25,000	− 1.33	7.13	0.07	0.02					9,970	1.23
	30,000	− 1.35	7.18	0.07	0.02					12,000	1.23
		Mean values		0.07	0.02						
Right angle end	15,000									6,440	1.32
	20,000	Non-planar distribution of stress..................								8,510	1.32
	25,000									10,710	1.33
	30,000									12,980	1.33

to the maximum stress is, from the curve in Fig. 8, 0.00331 inch. Thus the mean elongation over a length of 4 inches for a load of 20,000 pounds is $\frac{0.00331}{1.945} = 0.0017$ inch. This corresponds to a value of E given by $E = \frac{20000}{1.60} \times \frac{4}{0.0017} = 29.4 \times 10^6$ pounds per square inch. Proceeding in this manner, values of E were found for all the loadings at the central sections of the specimens, and the mean results are given at the heads of Tables I, II and III. The variations of E found in this way may be taken as a measure of the maximum over-all error in observation, measurement of the loads, calibration of the extensometers, plotting and calculation, and due to variations in the material. For Specimen I the maximum variation was 5 per cent., but this was in two cases only, the rest of the readings giving results which did not differ more than 2 per cent. The results for Specimen II were similar, while for the double angle, taking a mean of both angles, the deviation was in no case greater than 1 per cent.

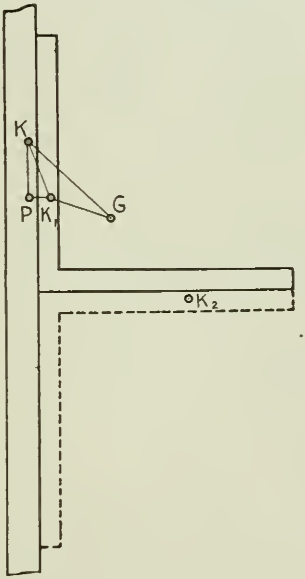
§3. *Discussion of the Results—General.*

If the load axis remained unchanged relatively to the section as the load increased, all the mean straight lines for any particular section would pass through the same points and the position of the neutral axis would be independent of the load. An inspection of the curves, Figs. 8 to 21, will show that this is not the case, and the discrepancy is due to the alteration of the load axis owing to lateral bending of the specimen. When this is allowed for by referring all load axes to the mean section through the end connections, the corrected axis remains practically constant as the load increases, as may be seen from the results given in Table IV, column 5. This is especially noticeable at the central sections. At the end sections there is in every case a slight shift, as the load increases, away from the centroid of the section perpendicular to the end plate and towards the centroid parallel to the end plate. This is probably due to a change in the fixing couple at the ends as the load increases.

§4. *The Effect of Constraints.*

In the case of single angles having long, narrow end plates the experimentally-determined load axis at the central section corrected for deflection never deviated more than 0.02 inch from the line of rivets. In the present tests y_k varies from 0.40 inch to 0.57 inch, while the y coördinate of the line of rivets is 0.90 inch. Thus the deviation from the line of rivets ranges from 0.33 inch to 0.50 inch. The reason for this is that the end plates in the present case are very much stiffer in their own plane than those used in the earlier experiments. The effect of such end constraints upon the position of the load axis and on the ratio of maximum to mean stress will first be considered in general. Let K in Fig. 22 represent the position of the load axis when there are no end constraints and K_1 its position as altered due to partial fixing. Assuming a normal load N, the bending couple in the former case would be $N.KG$ and in the latter $N.K_1G$, the restraining couple being thus $N.KK_1$. This couple may be resolved into the components $N.KP$ and $N.K_1P$ respectively parallel and perpendicular to the end plate. If the end connection consists of a gusset plate only, the former couple is the restraint due to its stiffness against bending in its own plane and the latter that due to its stiffness against bending perpendicular to its plane. It will readily be seen

FIG. 22.



that the former must be much greater than the latter for an ordinary thin plate, and thus KK_1 will be nearly parallel to the connected leg. A lock angle may act in two ways. It may restrain the bending more or less and it may transfer part of the load to the line of rivets by which it is connected to the main angle (K_2). The latter would cause a movement of the line of pull along KK_2, and the former a somewhat similar motion, so that the two effects cannot be separated.

The effect of these changes of axis upon the ratio of maximum to mean stress may be studied by means of the S-polygon. Fig. 2 represents this polygon for the section of Specimen I (slightly heavier than the standard 3 inches × 3 inches × ¼ inch angle) calculated as described above. The polygon is drawn to the same linear scale as the angle, so that the maximum bending stress for a position K of the load axis is given by $N \cdot \frac{KG}{LG}$ as described in Part I. The load is applied through one row of rivets 1.75 inch from B, in the leg AB. Thus if there is no restraint due to the end plate, the position of the load axis will be approximately K. (The exact position of K perpendicular to the connected leg will depend to some extent upon the lateral bending, but may, for purposes of illustration, be taken on the outside face of the connected leg.) In this case the ratio of maximum to mean stress will be

$$A\left(\frac{1}{A} + \frac{KG}{LG}\right) = 1 + \frac{A \cdot KG}{LG} = 2.82,$$

and the maximum stress will occur at the corner A. If, however, a constraining couple be introduced parallel to AB, the point of loading will move from K along AB toward B. As the couple increases the ratio $\frac{KG}{LG}$ will obviously decrease until the point K_1 on the line joining the apex (ab) to G is reached. Thus the restraining couple will obviously decrease the ratio of maximum to mean stress. At the point K_1 this ratio is 1.89, a decrease of 33 per cent., and the stress is constant over AB. From K_1 to B the ratio $\frac{KG}{LG}$ again increases, and thus the ratio of maximum to mean stress increases. At the point K_2, level with the centroid of the angle, this ratio is 3.18, greater than without constraint. Thus the most favorable position of the load axis is on the line joining the apex (ab) to the centroid. From this it will be seen that an increase of constraint is not always an advantage.

With the load axis in any of the positions considered it will be noticed that a constraint perpendicular to the end plate, causing K to move inwards, always leads to a decrease of $\frac{KG}{LG}$, *i.e.*, a decrease in the ratio of maximum to mean stress. The only effective way of obtaining such restraint is by having another angle back to back with the first, *i.e.*, a double-angle section. In this case, as will be seen later, there is a very considerable restraining couple parallel to BC, causing the stress to be much more evenly distributed over the section. This is the correct way of considering such a section, and not as one piece bending about a neutral axis parallel to BC, as is often done. These points will be discussed when the experimental results upon the double angle are considered.

The effects of constraints upon the distribution of stress in other types of section, such as unequal-legged angles, Z-sections, etc., may be considered in a similar manner by use of the S-polygon.

§5. *Experimental Results.* (a) *The Restraining Effect of the End Plates.*

The results of the tests on the specimens with the lock angles removed will first be considered in order to find the restraining effects due solely to the end plate. The restraining couple perpendicular to the end plate,—*i.e.*, in the direction Ox,—is difficult to ascertain exactly, because it is neither certain where the load enters the angle nor exactly what is the position of the load axis through the thickness of the end plate. In Table IV, column 5, the position of x_k relative to the mid-section of the rivets is given, and it may be remarked that it remains practically constant as the load increases in each of the Specimens I and II, although it is not the same for each, the mean being $x_k = -0.91$ for Specimen I and $x_k = -1.00$ for Specimen II. In any case, however, the effect of this restraint is small and the specimen may be considered as practically free to bend perpendicularly to the end plate. This result is in agreement with the earlier experiments made with narrow end plates. In these it was found that $x_k = -0.91$ both with an end plate ¼ inch thick and with one ¾ inch thick.

The case of the double angle is quite different. The two angles, back to back, prevent each other from bending perpendicularly to the end plate, and the result is an almost complete fixing in that direction, considerably decreasing the ratio of maximum to mean stress over the section. Again, the effect is practically independent of the load and is, as might be expected, the same for each angle. The arms of the fixing couples parallel to Ox, measured from the back of the main angles, are given in the annexed table.

TABLE V.

Load	Left angle	Right angle
15,000..........	0.77	0.77
20,000..........	0.77	0.76
25,000..........	0.77	0.77
30,000..........	0.77	0.76
Mean..........	0.77	0.77

The fixing parallel to the end plate is much more important for the single angles and of equal importance for the double angle. The annexed table shows the distance, measured parallel to Oy, of the actual axis from the line of rivets for each of the specimens at the central section:

TABLE VI.

Load, pounds	Specimen I, inch	Specimen II, inch	Double angle		
			Load, pounds	Left, inch	Right, inch
5,000...	0.41	0.33	15,000...	0.87	0.88
10,000...	0.42	0.35	20,000...	0.87	0.88
15,000...	0.44	0.36	25,000...	0.86	0.88
20,000...	0.43	0.36	30,000...	0.86	0.88
Mean...	0.42	0.35	Mean...	0.86	0.88

It will be noticed that there is fair agreement between Specimen I and Specimen II, although the line of pull on the end plate is different in the two cases. The fixing moment of the double angle, however, is more than twice that of the single angle.

In the earlier experiments on single angles connected to long, narrow gusset plates the line of pull, as mentioned above, never deviated more than 0.02 inch from the line of rivets. This shows the important effect of the type of gusset plate upon the position of the load axis and hence on the maximum stress in the member. The latter, of course, depends upon the lateral bending of the specimen, and in calculating the figures in column 7, Table IV, the axis of loading was not corrected for deflection. It will be noticed that, with a few exceptions, the ratio at the central sections decreases as the load increases. This is due to the alteration of the axis due to lateral bending. In every case the ratio is much less than for a load coinciding with the line of rivets, showing the value of a wide and firmly-connected gusset plate. The ratios of maximum to mean stress for a line of pull having the same x_k as that given by the experimental results, but y_k in line with the rivets, have been found by means of the S-polygon, as described above, and are compared with the actual ratios in the annexed table.

TABLE VII.

Load, pounds	Specimen I			Specimen II		
	Actual	Line of pull in line of rivets	Decrease due to fixing	Actual	Line of pull in line of rivets	Decrease due to fixing
			Per cent.			*Per cent.*
5,000.....	1.96	2.62	25.2	1.94	2.80	30.7
10,000.....	1.86	2.66	30.0	1.93	2.83	31.8
15,000.....	1.82	2.69	32.4	1.90	2.86	33.6
20,000.....	1.79	2.70	33.7	1.83	2.88	36.5

The average decrease of the ratio of maximum to mean stress due to the stiffness of the end plate in its own plane is thus about 35 per cent. at the highest load, the load axis (K^1, Fig. 2) being brought almost into its most favorable position as described in the last section.

At the end sections the ratio of maximum to mean stress is always greater than at the centre, the percentage increase being as shown in the annexed table.

TABLE VIII.

The Ratio of Maximum to Mean Stress at the End Section Compared with that at the Central Section.

Load, pounds	Specimen I			Specimen II		
	End	Central	Per cent. increase	End	Central	Per cent. increase
5,000.....	2.04	1.96	4.1	2.18	1.94	12.4
10,000.....	2.05	1.86	10.2	2.09	1.93	8.3
15,000.....	2.06	1.82	13.2	2.09	1.90	10.0
20,000.....	2.07	1.79	15.6	2.03	1.83	10.9
	Double angle					
	Left			Right		
	End	Central	Per cent. increase	End	Central	Per cent. increase
15,000.....	1.39	1.11	25.2	1.32	1.22	8.2
20,000.....	1.40	1.11	26.1	1.32	1.24	6.5
25,000.....	1.38	1.10	25.5	1.33	1.23	8.1
30,000.....	1.38	1.09	26.6	1.33	1.23	8.1

It will be noticed that the percentage increase varies widely, as might be expected. Tertiary stresses are indicated, ranging from 4 per cent. to 15 per cent. for the single angles and rising as high as 26 per cent. for the double angles. The curves for the latter show that the distribution of stress departed greatly from the planar. There is probably a readjustment of the longitudinal variations of stress at the different loads, depending upon the end connections, so that the results are not so reliable as at the central section and the exact tertiary stresses are thus indeterminate. They are local, however, and thus not so important, and may probably be neglected in designing if ordinary working stresses are used and the correct variation of stress over the main part of the member considered.

§5. (b) *The Effect of Lock Angles.*

It is often claimed, as stated in the introduction, that lock angles considerably reduce the ratio of maximum to mean stress in the member, some authorities going even so far as to say that when a lock angle is used the stress is practically uniformly distributed. A glance at the adjoined table will show how far this is from being the truth.

TABLE IX.

The Effect of Lock Angles on the Ratio of Maximum to Mean Stress at the Central Cross-sections.

Load, pounds	Specimen I			Specimen II		
	Ratio of maximum to mean stress		Per cent. change due to lock	Ratio of maximum to mean stress		Per cent. change due to lock
	With lock	Without lock		With lock	Without lock	
			Increase			*Decrease*
5,000.....	2.08	1.96	6.1	1.95	1.95	0
10,000.....	2.05	1.86	10.2	1.83	1.93	5.2
15,000.....	2.00	1.82	9.9	1.82	1.90	4.2
20,000.....	1.94	1.79	8.4	1.78	1.83	2.7
	Double Angle, left.			Double angle, right.		
			Decrease			*Decrease*
15,000.....	1.06	1.11	4.5	1.19	1.22	2.5
20,000.....	1.06	1.11	4.5	1.19	1.24	4.0
25,000.....	1.05	1.10	4.5	1.18	1.23	3.2
30,000.....	1.05	1.10	4.5	1.18	1.23	3.2

This table compares the ratio of maximum to mean stress with the lock angles in position and with them removed. Considering the single angles first, it will be seen that in the case of Specimen II the ratio of maximum to mean stress is decreased about 3 per cent. at working load by the use of the lock angle, while in Specimen I it is actually greater by about 8.4 per cent. with the lock angle than without it. In the case of the double angle the stress in one leg is decreased about 4.5 per cent. and in the other 3.2 per cent. It is thus evident that the effect of the lock angle is very small, and that it is practically worthless for the purpose of distributing the stress more uniformly.

The variability, and apparently paradoxical character of these results will be explained by a consideration of the shift of the load axis due to the lock angle as displayed by the adjoined table.

It will be seen that in all cases, as might be expected, the lock angle slightly increases the arms of the restraining couples both perpendicular to and parallel to the end plate. The change of y_k ranges from 0.07 inch to 0.09 inch, while that of x_k is 0.10 inch in all cases except Specimen I, in which it is only 0.01 inch. The agreement between the results in the different cases is remarkable, especially considering that no care was taken to get uniform work-

TABLE X.

Change of Load Axis at Central Section Due to Lock Angle.

Load, pounds	x_k		Shift toward centroid produced by lock, inches	y_k		Shift toward centroid produced by lock, inches
	With lock, inches	Without lock, inches		With lock, inches	Without lock inches	
	Specimen I					
	—	—		+	+	
5,000.....	0.89	0.92	0.03	0.41	0.49	0.08
10,000.....	0.89	0.90	0.01	0.40	0.48	0.08
15,000.....	0.90	0.90	0.00	0.40	0.46	0.06
20,000.....	0.91	0.92	0.01	0.40	0.47	0.07
	Mean displacement...		0.01	Mean displacement.		0.07
	Specimen II					
	—	—		+	+	
5,000.....	0.91	1.00	0.09	0.48	0.57	0.09
10,000.....	0.88	1.01	0.13	0.46	0.55	0.09
15,000.....	0.89	1.00	0.11	0.46	0.54	0.08
20,000.....	0.91	1.00	0.09	0.46	0.54	0.08
	Mean displacement...		0.10	Mean displacement.		0.08
	Double angle	*Left*				
	+	—		—	+	
15,000.....	0.02	0.08	0.10	0.05	0.03	0.08
20,000.....	0.02	0.08	0.10	0.05	0.03	0.08
25,000.....	0.02	0.08	0.10	0.04	0.04	0.08
30,000.....	0.02	0.08	0.10	0.04	0.04	0.08
	Mean displacement...		0.10	Mean displacement.		0.08
	Double angle	*Right*				
	+	—		—	—	
15,000.....	0.03	0.07	0.10	0.11	0.02	0.09
20,000.....	0.03	0.08	0.11	0.11	0.02	0.09
25,000.....	0.03	0.07	0.10	0.11	0.02	0.09
30,000.....	0.02	0.07	0.09	0.10	0.02	0.08
	Mean displacement...		0.10	Mean displacement.		0.09

manship in the making of the specimens. It may be said that the lock angle produces an increase of, roughly, $^1/_{10}$ inch in the arms of each of the restraining couples. Now the effect of this depends upon the position of the load axis due to the stiffness of the end plate. In Specimen I the displacement of the axis brings the *GL* line of the S-polygon from *GL′* to *GL″* (Fig. 2). *L* thus passes over from the *a* line to the *b* line, and the maximum stress is actually increased by the additional restraint. In the other specimens the point L remains on the a line, and thus the restraint slightly diminishes the maximum stress.

The effect of the lock angle is no more marked at the end sections than at the central section, the change in the restraining arm due to its action varying from 0.02 inch to 0.10 inch.

TABLE XI.

The Effect of Lock Angles on the Ratio of Maximum to Mean Stress. End Sections.

Load, pounds	Specimen I Ratio of maximum to mean stress			Specimen II Ratio of maximum to mean stress		
	With lock	Without lock	Decrease due to lock	With lock	Without lock	Decrease due to lock
			Per cent.			*Per cent.*
5,000.....	2.04	2.04	0.0	2.08	2.18	4.6
10,000.....	1.98	2.05	3.4	2.00	2.09	4.3
15,000.....	1.98	2.06	3.9	1.96	2.09	6.2
20,000.....	2.00	2.07	3.4	1.90	2.03	6.4
	Double angle					
	Left			Right		
15,000.....	1.26	1.39	9.3	1.19	1.32	9.9
20,000.....	1.26	1.40	10.0	1.19	1.32	9.9
25,000.....	1.30	1.38	5.8	1.19	1.33	10.5
30,000.....	1.29	1.38	6.5	1.14	1.33	14.3

TABLE XII.

Change of Load Axis Due to Lock Angles. End Sections.

Load, pounds	x_k (inches)			y_k (inches)		
	With lock	Without lock	Change due to lock	With lock	Without lock	change due to lock
Specimen I						
5,000...	0.95	1.00	0.05	0.51	0.61	0.10
10,000...	0.97	1.02	0.05	0.50	0.62	0.12
15,000...	0.97	1.03	0.06	0.50	0.61	0.09
20,000...	0.97	1.04	0.05	0.51	0.60	0.09
			0.05			0.10
Specimen II						
5,000...	0.95	0.99	0.04	0.60	0.65	0.05
10,000...	0.91	0.96	0.05	0.58	0.61	0.03
15,000...	0.96	0.97	0.01	0.56	0.61	0.03
20,000...	0.96	0.96	0.00	0.54	0.58	0.04
			0.02			0.04

It produces a slight decrease in the maximum stress, 3 per cent. to 7 per cent., for the single angles and a little greater, 6 per cent. to 10 per cent. and in one case 14 per cent., in the double angles. The results are more variable than at the centre, owing, no doubt, to the difference in the fixing couples near the rivets in the different specimens due to the different positions of the line of loading of the gusset plate.

To sum up, it may be said that neither in the single nor double angles does the lock angle cause a displacement of more than $^1/_{10}$ inch in the line of pull either parallel or perpendicular to the end plate, and that this produces only small changes in the maximum stress, insignificant in comparison with those arising from the stiffness of the gusset plate in its own plane. The effect of the lock angle is thus so small as to be practically negligible. It is also uncertain, since, depending upon the stiffness of the gusset plate, which is difficult to predict, it may increase or diminish the maximum stress. The contention that the lock angle increases the virtual length of attachment of the main angle to the gusset plate, allowing more rivets to be used, is also seen to be incorrect, since practically none of the stress is transmitted into the angle through the rivets in the lock angle, at any rate until the member is near to the breaking load, when it is of no importance. The tests of McKibben[12] have shown that the effect of lock angles upon the breaking load is uncertain and not great in any case.

It thus appears that lock angles are of very little practical value and are unnecessary, expensive and cumbersome additions to the end connections.

§5. (c) *The Effect of a Change in the Line of Loading of the Gusset Plate.*

In order to obtain some idea of the relative importance of this factor, the load axis on the end plate of Specimen II was altered by reboring the pin-hole and adding reinforcing plates, the change being from a line 0.85 inch from the corner of the angle,—*i.e.*, in line with the centroid of the section,—to one in line with the rivets, 1.75 inches from the corner. The effect of this upon the load axis in the specimen may be seen from the annexed table. There was practically no change at the central section, but at the end the arm of the fixing couple was decreased 0.10 inch perpendicular to the end plate and increased 0.21 inch parallel to the end plate. Thus only the tertiary stresses were affected by the change. A comparison of the load axes in Specimens I and II (Table XIV), which were practically similar (although one was a little heavier than the other), except that the load axis in Specimen I was in line with the back of the angle while in Specimen II it was in line with the centroid, as explained above, reveals a change of 0.08 inch in the arms of the restraining couples at the central section and a smaller change at the end. In this case the differences may, of course, have been partly due to other causes than the difference in position of the axis, but in both cases they were so small as to make it appear that the exact position of the load axis on the end plate is not of very much importance, the distribution of stress being practically fixed by the line of rivets and the stiffness of the gusset plate. The effect on the tertiary stresses may be greater, but does not seem worthy of further investigation in view of its smallness in comparison with that due to the stiffness of the end plate in its own plane.

---

[12] *Proc. Am. Soc. Test. Mat.*, vol. 6, p. 267; vol. 8, p. 287.

TABLE XIII.

Specimen II.—Effect of a Change in the Load Axis.

Load, pounds	x_k (inches)			y_k (inches)		
	Axis in line with centroid	Axis in line of rivets	Change	Axis in line with centroid	Axis in line of rivets	Change
Central Section.						
5,000...	1.00	1.00	0.00	0.57	0.57	0.00
10,000...	1.01	1.00	0.01	0.55	0.55	0.00
15,000...	1.00	0.99	0.01	0.54	0.54	0.00
20,000...	1.00	0.99	0.01	0.54	0.52	0.02
		Mean.....	0.01		Mean.....	0.00
End Section.						
5,000...	0.99	1.08	0.09	0.65	0.40	0.25
10,000...	0.96	1.08	0.12	0.61	0.41	0.20
15,000...	0.97	1.07	0.10	0.61	0.40	0.21
20,000...	0.96	1.06	0.10	0.58	0.41	0.17
		Mean.....	0.10		Mean.....	0.21

TABLE XIV.

Comparison of the Load Axes in Specimens I and II.

Load, pounds	x_k (inches)			y_k (inches)		
	Specimen I	Specimen II	Difference	Specimen I	Specimen II	Difference
Central Section.						
5,000...	0.92	1.00	0.08	0.49	0.57	0.08
10,000...	0.90	1.01	0.11	0.48	0.55	0.07
15,000...	0.90	1.00	0.10	0.46	0.54	0.08
20,000...	0.92	1.00	0.08	0.47	0.54	0.07
		Mean.....	0.09		Mean.....	0.08
End Section.						
5,000...	1.00	0.99	0.01	0.60	0.65	0.05
10,000...	1.02	0.96	0.06	0.61	0.61	0.00
15,000...	1.03	0.97	0.06	0.62	0.61	−0.01
20,000...	1.04	0.96	0.08	0.61	0.58	−0.03
		Mean.....	0.05		Mean.....	0.00

§6. *Further Remarks on the Double Angle.*

It is the usual practice in designing a member, such as Specimen III, made up of two angles back to back, to consider that bending occurs about a neutral axis parallel to the unconnected legs, the whole member bending as one piece. It has already been shown by the writer [13] that this is incorrect and that the only true way in which to regard this and other similar built-up sections is to consider that each element of the section tends to bend about an individual neutral axis, being restrained more or less by the end or other connections. It is only necessary to remark here that the present experiments bear out this theory and also show that a stiff end plate produces such large constraining moments that almost complete fixing results, the greatest deviation of the load axes of the two angles from their centroids in Specimen III being about 0.1 inch. How far this fixing may be relied upon in any particular case it is difficult to say, and the subject is worthy of further investigation.

§7. *General Conclusions.*

The above analysis leads to the conclusion that, with a gusset plate connection of the usual type, wide and rigidly connected, the chief factor influencing the distribution of stress over the cross-section of the member is the stiffness of the end plate in its own plane. In comparison with this the effect of lock angles is practically negligible, and a considerable change in the line of pull on the gusset plate may be made without appreciably altering the stress distribution.

---

[13] *Loc cit.*

The bearing of the above upon the design of single- and double-angle members is obvious, although it is difficult to formulate exact rules. It may, however, be definitely stated that lock angles are of little, if any, value, and this is perhaps the most important result of the investigation. As to the correct ratio of maximum to mean stress to be used in designing, the earlier experiments of the writer [14] have shown that with long, narrow gusset plates, unconnected at the sides, there is practically no end restraint, no matter what the thickness, within practical limits, of the plate may be, and that a fairly good approximation to the actual distribution of stress may be obtained by considering the load axis as coinciding with the line of rivets and lying slightly within the end plate. A broad, stiff connection, however, is generally advisable, and with this the ratio of maximum to mean stress is much, say 30 per cent., lower than would be given by the above rule. It is difficult to estimate exactly, however, and perhaps the same rule might be used taking a higher value for the working stress, since the tertiary stresses would also be covered by it. With a narrow plate, however, the ordinary working stress should be used, since the tertiary stresses are not included. There remains, of course, the possibility of exceeding the yield point at certain fibres without danger. This, however, it would not be safe to rely upon in the present state of experimental knowledge of the subject.

The experiments on double-angle members show that such a member with a stiff end plate is an excellent type in practice, the stress being almost uniformly distributed at the central section, but, unfortunately, it seems to be impossible to predict exactly what the distribution will be in any particular case.

---

[14] In the earlier paper (*loc. cit.*) it was stated that the end plate had little constraining effect. This should be modified, in the light of the present experiments, to the statement given above.

§8. *Summary and Conclusion.*

The chief conclusions to which the present paper leads are:

1. That the only practicable experimental method at present available for investigating the distribution of stress in built-up members is by means of some form of extensometer, and that the simplified mirror extensometer used in the tests described is very suitable for this purpose.

2. That the assumption of a planar distribution of stress is justifiable in such members as are considered here, except perhaps close to the end connections, and that the ordinary theory may therefore be applied to an analysis of the distribution of stress in these members.

3. That in single- and double-angle tension members connected at their ends by means of rivets to wide and rigidly held gusset plates the stiffness of the gusset plate in its own plane has a considerable effect on the distribution of stress in the member, there being in every case a particular stiffness which will give the least maximum stress in the member for a given load.

4. That in such members lock angles are of very little, if any, value for the purpose either of giving a more equable distribution of stress in the member or of increasing the effective length of end connections.

5. That a slight change in the line of application of the load to the gusset plates does not materially affect the distribution of stress in the member, except possibly close to the end connections.

6. That the experiments on double angles bear out the theory that such members do not act as a single piece bending as a beam.

7. That the experiments lead to certain rules for design as formulated in Part III, §7.

In conclusion the writer wishes to thank Professors H. M. Mackay and E. Brown, of McGill University, for their personal interest and advice; and Mr. S. D. Macnab, of the McGill Testing Laboratory, who was associated with him throughout in the experimental work.

McGILL UNIVERSITY, Montreal,
January, 1915.

MODERN THEORIES OF MAGNETISM.*

BY

GEORGE FLOWERS STRADLING, Ph.D.,

Head of Science Department, Northeast High School, Philadelphia.
Member of the Institute.

As I must frequently employ certain words which are not in familiar use, it seems desirable that I should at first endeavor to make their meaning clear. Permit me, therefore, to recall to your minds some of the phenomena of magnetism. I take this steel bar and dip its end into this pile of nails. The clinging of the nails to the intruder shows us that it is magnetized. I bring an end of the bar near the north end of a compass needle and you notice a distinct manifestation of force, now attraction and again repulsion when I cause the other end of the bar to approach the same end of the needle. Both ends of the bar magnet are alike in picking up the nails, but they differ in their effect upon the compass needle. We thus see that there are two kinds of magnetism. I give the bar an opportunity to follow its own bent. You perceive that it faithfully turns into an approximately north and south line. Marking with chalk the north-seeking end of the bar, I bring it first to one end, then to the other end of the compass needle. I reverse the bar and apply its south-seeking end. You have seen both attraction and repulsion, and if you have noticed carefully you may have drawn the conclusion that north and south poles attract, while like poles (north and north or south and south poles) mutually repel.

A rough experiment shows us that the forces between two magnetic poles, as are called the parts of the magnet which attract and repel most strongly, diminish rapidly as the distance between them is increased. Keeping this fact in mind, let us put the bar magnet somewhere near the north pole of the needle and proceed to consider why the latter is deflected. It is attracted by the south pole of the bar. It is repelled by the north pole of the bar. The two poles of the bar, if it is an orthodox magnet, are equally strong. Hence we must conclude that the pole of the bar magnet nearer to the needle has the preponderating influence just because it is nearer, and not because it is the stronger. It is opposed by its opposite pole, which is striving to do just the opposite thing to the needle, but which fails to win because it is too far off. If it were possible to keep the nearer pole just where it is and then to pull the magnet out along its length, as a candy-maker does taffy, until it were twice as long as at first, though both poles remain unchanged, then the nearer pole would be opposed more feebly by the distant pole and the needle would be deflected through a greater angle. Or, on the other hand, could the bar magnet dwindle in length until its two ends were only an inch apart, though no change in the strength of the poles had occurred, then the two antagonistic poles would be at so nearly the same distance from the end of the needle that their opposing attraction and repulsion would be almost equal, and their resultant would be small.

---

* Presented at the joint meeting of the Electrical Section and the Philadelphia Section, American Institute of Electrical Engineers, held April 1, 1915.

From these considerations it becomes evident that something more than the strength of the poles of a magnet must be known in order to determine its effects upon other magnets. The additional factor is the distance between its poles. The greater this distance the greater the resultant force exerted. The product of pole-strength by distance between the poles is designated the moment of the magnet. Just as in a lever you can double the equilibrating effect of a weight by removing it to twice the distance from the fulcrum, so in the case of a magnet you can double its force upon distant magnets by doubling the distance between its poles.

We could thus have two magnets of equal moment, one a metre from pole to pole, the other only half a metre. The first would have poles only half as strong as the second. So far as attracting or repelling a distant magnetic needle is concerned, these two magnets would be equivalent, yet the longer would have twice the volume of steel in it, if their cross-sectional areas were the same. In the smaller magnet the same moment is obtained with only half the volume of steel. In other words, if we divide the moment of each magnet by its volume we shall get quotients which are different and are as 1 to 2. This quotient is called the intensity of magnetization and designates how much moment the magnet has for each unit of volume. Should we divide the moment by the mass of the magnet the quotient would tell how much moment there is for each unit of mass, for each gramme. In this case the quotient is designated the specific intensity of magnetization.

How was the bar of steel magnetized? Perhaps by putting it inside a coil of wire in which an electric current was flowing. Before the bar was inserted there was a magnetic field within the coil. Let its strength be called H units; *i.e.,* let there be such a condition there that a unit magnetic pole would experience a force of H dynes. When the steel bar is inserted in this field it becomes magnetized. It has two poles, each of a certain strength. It has therefore acquired a magnetic moment, and has a corresponding intensity of magnetization and also a specific intensity of magnetization. These effects are due to the field strength of H units. The quotient got by dividing the intensity of magnetization by H is called the susceptibility of the specimen of steel. The corresponding quotient got by dividing the specific intensity of magnetization by H is called the specific susceptibility, and is designated by the Greek letter χ.

I have now finished the definition of technical terms.

There are good reasons for believing that the molecules of steel are all individual magnets, and are so all the time, before the bar has been magnetized as well as afterwards. The process of magnetization is thought to consist in bringing about an orderly arrangement in the mass of tiny magnets which had been located in an entirely haphazard way, so that as many north poles had pointed in any given direction as south poles, with the result that the opposite poles neutralized each other in effect. When the rod of iron or steel is put in a magnetic field,—that is, near a permanent magnet or in a coil carrying a current,—the magnetizing force causes the little molecular magnets, in part at least, to turn so that their axes lie in the direction of the magnetic lines of force. When the rod is taken away from the field of force it still keeps some magnetism, but if it is struck or heated so that the molecules are stirred up they resume their fortuitous arrangement and the rod loses a part of its magnetism.

There are three classes of substances in respect to magnetic behavior.

1. *Diamagnetic.*—Such as are repelled by a magnet and seek to set themselves with their axes at right angles to the lines of force or, more accurately, seek to move from the strongest to the

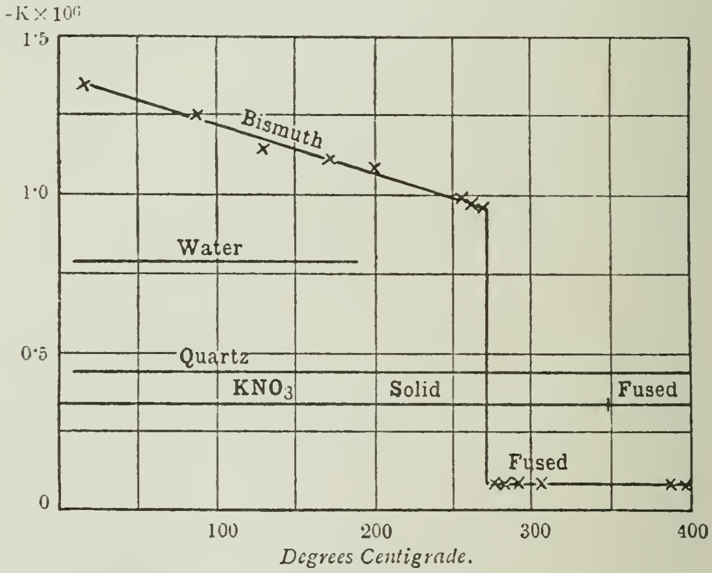
weakest part of the magnetic field. The force called forth, however, is always small. Bismuth exhibits diamagnetism to the highest degree.

2. *Paramagnetic.*—Such as are feebly attracted by a magnet and strive feebly to move from the weakest to the strongest part of a magnetic field. Oxygen and platinum are examples.

3. *Ferromagnetic.*—These are iron, steel, nickel, cobalt, and some alloys. They are strongly attracted by a magnet.

Diamagnetic substances are most numerous, then come paramagnetic, and, finally, the small but important group of ferromagnetic substances. This last class is best known because its members exert a much greater magnetic force than do representatives of the two other groups.

FIG. 1.



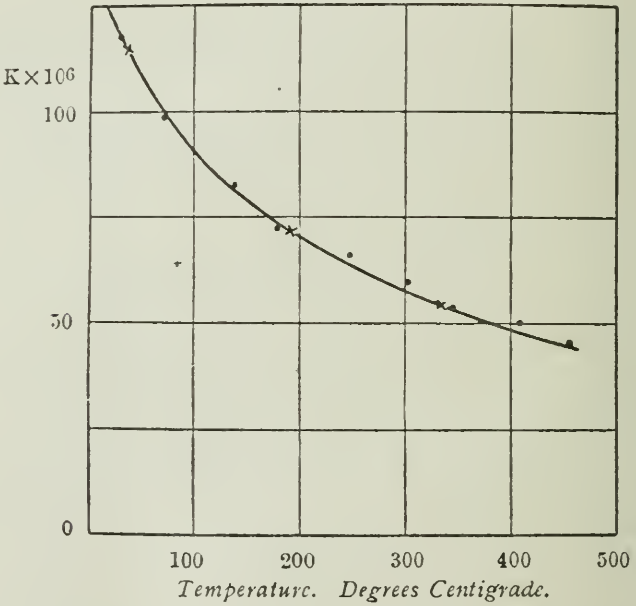
As the history of magnetism runs back to the time when the mythical Greek shepherd felt the nails of his shoes cling to the rock, I must set an arbitrary limit to the extension of the word "Modern" in the title of my lecture. I will therefore begin twenty years ago. In 1895 Pierre Curie, whose work in connection with radium has eclipsed his other excellent physical investigations, published an important paper on magnetism. He set himself the problem of studying the magnetic properties of diamagnetic, paramagnetic, and ferromagnetic substances when the temperature and the intensity of the magnetic field changed. His temperature range was from room temperature to 1370° C. Let us look at some of his results with diamagnetic substances. The ordinates represent specific susceptibility, while the abscissæ are temperature. Notice that water, quartz, and saltpetre keep the same susceptibility over a wide range of temperature. The water was in a closed vessel and was thus kept in a liquid state up to 199° C. The comportment of bismuth is worthy of your consideration. At 20° it has a susceptibility of -1.3×10^{-6}. As the temperature rises this falls linearly until at 273° it has dwindled to $-.96 \times 10^{-6}$. At this temperature the bismuth melts and the susceptibility of the liquid is only one-twenty-fifth of that of the solid at the same temperature. When the temperature of the molten substance is still further raised it comports itself just as do the other substances shown on the slide; *i.e.,* it shows a susceptibility independent of temperature. Saltpetre shows no change of susceptibility upon melting.

For all the substances investigated he found that the magnetic moment was proportional to the strength of the field throughout the range he employed. The susceptibility was therefore independent of the strength of the field as well as of the temperature. Let us keep in mind, however, that antimony and bismuth transgress this rule as their temperature rises.

Like diamagnetic substances, paramagnetic bodies were found to maintain the same susceptibility as the field strength changed, but, unlike diamagnetic substances, they were found to have a smaller susceptibility as the temperature rose. Look at the diagram showing Curie's results for oxygen. The points indicating the experimental results do not lie on a straight line. Let the temperatures be changed from the Centigrade to the absolute scale by adding 273° to the former reading. Then take the susceptibility at any temperature and multiply it by that temperature on the absolute scale. The product will be found to be about 33700×10^{-6}. For example, at 75° C. = 348° abs. the susceptibility is 98×10^{-6}. The product $348 \times 98 \times 10^{-6} = 34104 \times 10^{-6}$. For 452° the corresponding product is $(452 + 273) \times 46.9 \times 10^{-6} = 34002.5 \times 10^{-6}$. This agreement of the two products is striking, especially as the difference in temperature of the two observations was 377° C. The name "Curie constant" has been given to this constant product.

Curie phrases the law thus: "From 20° to 450° C. the specific susceptibility of oxygen varies inversely as the absolute temperature." The same law holds approximately for the metal palladium and for several salts in solution. As has been said, it was found in the case of diamagnetic substances that a change in the strength of the magnetic field made no difference in the specific susceptibility. We note then that this property of diamagnetic and paramagnetic substances is for both independent of the field strength, but does depend upon the temperature for paramagnetic substances, while it does not so depend for diamagnetic bodies. This difference in behavior led Curie to conclude that "these results are in favor of theories which attribute paramagnetism and diamagnetism to causes of different natures."

FIG. 2.

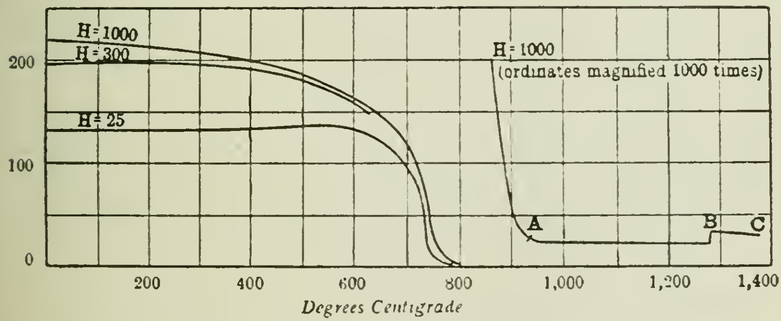


Temperature. Degrees Centigrade.

It has been found, however, that even for oxygen the law connecting temperature with susceptibility changes as low temperatures are reached. Moreover, Du Bois and Honda found paramagnetic substances in which a change in temperature made no change in the susceptibility.

Curie extended his experiments to the third class of substances, viz., ferromagnetic, and found many interesting things. This curve traces the magnetic history of soft iron from 0° C. to beyond 1300° C. To the left are three curves for different field strengths. Notice how nearly parallel to the horizontal axis the $H = 25$ curve runs. Since the ordinates here give intensity of magnetization, while the abscissæ give temperature Centigrade, this parallelism means that with this strength of field the piece of iron maintained the same intensity during a rise of temperature of several hundred degrees. However, when the strength of the field was 1000 units the intensity fell from the first as the temperature rose. Both curves drop very suddenly at about 750° C., the so-called Curie point, and when 800° is reached there is but little magnetic intensity left. This explains why a magnet will not pick up a white-hot nail, but will pick it up when it has cooled to perhaps 700°. The right-hand curve has its ordinates magnified 1000 times. From 800° to about 860° they are too great to be represented on the diagram. At *A,* 930°, the slope grows less and is very slight up to *B,* 1280°, where all at once the intensity becomes fifty per cent. greater. After this the curve again slopes downward. In the left of the diagram iron is ferromagnetic. At about 750° it changes continuously into a paramagnetic substance whose course is traced in the right of the figure. This change from ferro- to paramagnetic occurs for the mineral magnetite at 530° and for nickel at 340°.

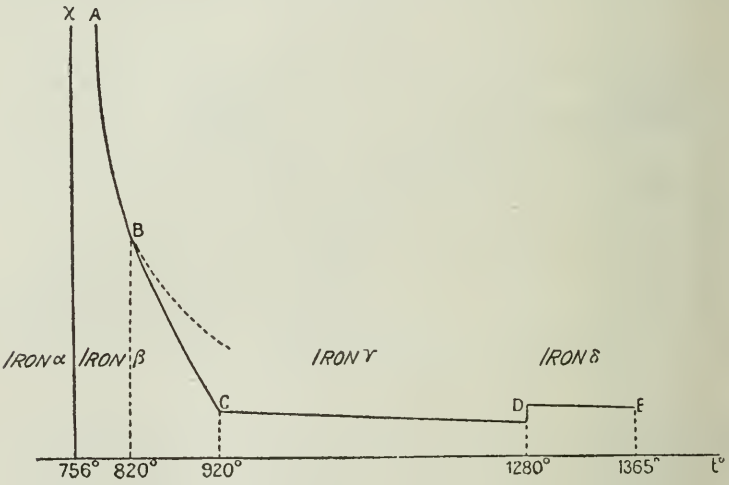
FIG. 3.



The following figure shows the same facts in a different way. The ordinates are specific susceptibility. Alpha iron, beta iron, gamma iron, and delta iron are limited by the temperatures 756°, 920°, 1280° C. When iron ceases to be strongly magnetic at 756° and its temperature is further raised, the susceptibility falls rapidly, as the curve shows. In the gamma state the decrease of susceptibility is very gradual. At 1280° C. there is a sudden rise, after which again a gentle decline occurs.

So far we have considered the connection between magnetization intensity and temperature. Let us give attention to the curve showing change of intensity with field strength. The ordinates here represent the former quantity and the abscissæ the latter. When the temperature of the specimen of iron is even as near the Curie point as 740.5° there is considerable rise in intensity of magnetization as the field strength increases. An elevation of temperature of a few degrees brings down this increase to a very modest amount. Compare the intensities for $H = 320$. An increase of 3.7° from 740.5° to 744.2° C. reduces the intensity to about half its value at the lower temperature, while the intensity for 820° is so small that it cannot be represented on the diagram. Notice further that the curve for 740.5° becomes a straight line for 749.9° and higher temperatures.

FIG. 4.

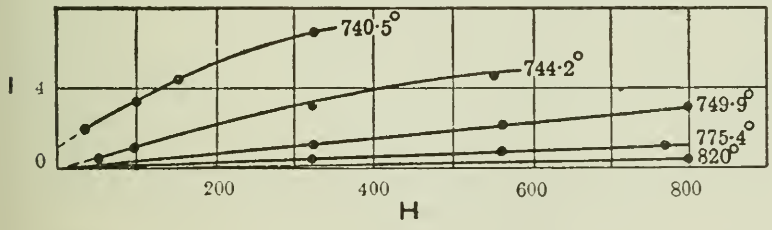


Curie pointed out the similarity in the form of the curves connecting, on the one hand, the density and temperature of a gas near the critical state and, on the other, the intensity of magnetism and temperature of iron near the Curie point. This analogy has been of use both in suggesting methods of expressing results and also in pointing to explanations of phenomena.

So far you must agree with me that I have failed to justify the title of this lecture as "Modern Theories of Magnetism." No theories, but only facts, obtained by experiment, have been presented.

In 1820, less than a month after Arago, before an audience of the French Academy including Laplace, Biot, and Ampère, had demonstrated Oersted's experiment proving an electric current to produce magnetic effects, one of that audience, Ampère, made the suggestion that magnetism might be due to currents of electricity circulating within the magnet. This theory in modern garb holds the field to-day. When it became accepted that the atom consists of electrons revolving about or in a charge of positive electricity it was very easy to make the guess that the cause of magnetism was to be sought in the motion of these electrons. They explain so much,—the conduction of both heat and electricity, the Zeeman effect, kathode rays, radioactivity,—that they tempted the theorist to impose one additional burden upon them,—that is, the phenomena of magnetism. The first attempts were, however, not successful. Both Sir J. J. Thomson, in England, and W. Voigt, in Germany, discussed at length the motion of these negatively-charged electrons without finding an explanation for the facts of magnetism. It remained for a Frenchman, Langevin, to find the clue. In 1905, ten years after Curie's work appeared, he made public his solution of the problem of diamagnetic and paramagnetic substances.

FIG. 5.



It may perhaps be well for us to recognize how complicated the problem of magnetism is in order that too much may not be expected at first of any explanation. I quote here from G. A. Schott[1]:

"1. Effects due to the mutual interactions of the molecules of the substance; these are usually taken to include hysteresis and coercive force, and the numerous interactions between strain and magnetism.

"2. Effects due to the actions between the atoms of a molecule. The smallness of the magnetism of oxides and salts of iron and cobalt in proportion to the amounts of iron or cobalt contained in them is an effect of this kind.

"3. Effects due to the constitution of the atom itself. The fact that the amalgams of iron and cobalt are as strongly magnetic in proportion to their concentration as the pure metals, coupled with the usual supposition, made on chemical grounds, that the molecule of a metal is monatomic, can hardly be explained except by supposing that magnetism is, in the last resort, an atomic property, and that the largeness of the magnetism of iron and its congeners is due to some peculiarity of atomic structure. This conclusion is supported by the experiments of St. Meyer and others, from which it results that atomic magnetism is a periodic function of the atomic weight, and is in some very close connection with the atomic volume."

As specific instances of phenomena in magnetism difficult to explain let these suffice:

1. The formation of Heusler's ferromagnetic alloys from copper, manganese, and aluminum, no one of which by itself is usually more than slightly magnetic, either positively or negatively.

2. The existence of manganese as paramagnetic or ferromagnetic according to past treatment.

3. The change of tin from a diamagnetic to a paramagnetic state. When gray tin, which is diamagnetic, is heated its negative specific susceptibility grows greater and at 35° C. reaches zero. It continues to rise with the temperature up to 50°. A further increase of temperature fails to affect it until the tin melts at 232°, when it suddenly drops to a value below zero and

---

[1] *Phil. Mag.*, Ser. 6, vol. xv, p. 172 (1908).

the liquid metal, a diamagnetic substance, retains this negative susceptibility as it rises still further in temperature.

4. The formation of iodide of mercury and potassium, a paramagnetic substance from three diamagnetic elements.

Surely no theory could hope to do more than explain the salient and general features of so complex a group of phenomena as magnetism presents to us.

LANGEVIN'S THEORY.

Every atom, according to current views of the constitution of matter, has a number of electrons revolving in closed orbits within it or about its centre. All electrons have equal charges of negative electricity. Our fellow-countryman, Henry A. Rowland, proved that a charge of electricity in motion produces magnetic effects just as a current does. Accordingly each electron moving in its orbit is equivalent to a current of electricity flowing in the same orbit. One face of the orbit is a magnetic south pole, the other a north pole, and magnetic lines of force surround the moving electron.

Let us fix our mental gaze on one such electron revolving in a circular path. Let a magnetic field be set up perpendicular to the plane of the orbit,—that is, so that a magnetic pole would be urged by the field to move at right angles to the plane of the orbit. There will be an interaction between the field of force and the electron in motion, with the result that the electron continues to revolve at the same distance from the centre of its path, but makes a revolution in a different time. As any change in the velocity of the electron will cause a change in the electric current to which it is equivalent, and as a change in the current will carry with it a change in the magnetic effect, it follows that a change in the magnetic moment of the orbit follows upon the arrival of the external magnetic field which affects the electron. Calculation shows that no matter in which direction the electron is revolving, the change in magnetic moment of the orbit is always in the same direction. For example, let the external field be that existing between the north and the south pole of a horseshoe magnet. The effect of this field upon an electron revolving in an orbit whose plane is at right angles to the line joining the poles of the magnet is to cause the orbit to strive to develop a north pole on its side toward the north pole of the magnet and a south pole on the other side. This kind of induction effect is characteristic of diamagnetic substances. Even if the electron is at rest when the magnetic field is applied, the result is about the same, for Lorentz has shown that the electron will be made to rotate about an axis parallel to the direction of the field and in such a direction as to make its lines of force oppose those of the external field.

Perhaps enough has been said to show how closely the modern theory is in fundamental agreement with the ideas of Ampère and of Weber. In 1896 Zeeman, in Holland, discovered that a yellow sodium flame put in a strong magnetic field suffers a change in the character of the light which it emits. As the motion of the electrons is regarded as the source of radiation, it will be noted that the Zeeman effect is allied with the diamagnetic effect of a magnetic field outlined above. Since the Zeeman effect is found to occur in nearly all spectral lines of nearly all substances which have been examined, we are led to think that the diamagnetic effect of a magnetic field is very general; that it occurs in substances classed as paramagnetic or ferromagnetic as well as in diamagnetic bodies. Let us see how Langevin accounts for this.

Each atom has several electrons revolving in orbits. These orbits may be in distinct planes or may differ in other ways. The total magnetic moment of the atom will be found by summing up, with proper regard to direction and magnitude, the magnetic moments of the separate orbits. The result of this integration must give one of two results, either zero or some significant quantity. Langevin investigated the effect of the external magnetic field on an atom having no initial resultant magnetic moment. As the magnetic effects of the various electrons neutralized each other the atom as a whole would not rotate when an external field was applied, as it would tend to rotate were there a single orbit, in an endeavor to set the axis of the orbit in coincidence with the direction of the magnetic field. Even if the orbits were not perpendicular to the direction of the field the general effect would be unaltered. Although the total magnetic moment of the atom was zero before the imposition of the magnetic field, this does not cause to follow that the total change in the magnetic moment would be zero. On the contrary, the changes in the various electronic circuits are in the same sense. Langevin's theory expresses the ratio of the change in the magnetic moment to the original magnetic moment of an orbit in terms of quantities whose magnitude is known. By using this relation it is found that the greatest attainable strength of magnetic field would change the magnetic moment of a diamagnetic atom by about one part in ten thousand.

Does Langevin's theory have anything to say about Curie's statement that the susceptibility of diamagnetic substances changes in general neither with temperature nor with field strength? With regard to the connection between susceptibility and field strength, his theory shows that the magnetic intensity is proportional to the strength of the field. Since susceptibility is the quotient of the first of these quantities by the second it follows that this quotient is constant. In relation to the connection between temperature and susceptibility let it be noticed that Langevin finds nothing to occur outside of the atom when the magnetic field is applied. The atom as a whole does not rotate nor receive motion of translation. The application of a magnetic field will not cause it to affect in a different way the motion of its neighbors, nor will it make them affect its motion differently. If both it and its neighbors rise in temperature their motion will be changed, but that increase of kinetic energy will not affect what goes on within the atom. In short, in a diamagnetic substance the application of an external magnetic field will not produce any thermal effect, nor will a change of temperature bring in its train any magnetic effect. The susceptibility will be independent of temperature, as indeed Curie showed it to be in several substances. As has already been pointed out, he found bismuth to be an exception to this rule, and more recently other investigators have increased the list of exceptions. Honda and Owen have found diamagnetic substances whose susceptibility increases with temperature, others in which that property diminishes with temperature in addition to those for which it remains constant during temperature change. Were bismuth the only exception, an explanation might be found in the effect of the magnetic field upon its free electrons, those electrons which give it electric and thermal conductivity. It is known that the free path of these electrons is much longer than is commonly the case.

As has been stated before, the motion of the electrons within the atom produces light. The fact that the wave-length of the emitted light is scarcely affected by a change of temperature is quite in line with the absence of an effect of temperature upon magnetic moment, since a change in the motion of the electron would affect both its light emission and its magnetic moment.

Let us turn next to Langevin's theory of paramagnetic substances. Here again the atoms have revolving electrons, each having a definite magnetic moment. In diamagnetic substances the summation of the moments of the various orbits gave zero. In both paramagnetic and ferromagnetic bodies Langevin assumes the summation to give a resultant moment which is not zero. What will occur when an external magnetic field is imposed on the atom? First, in every orbit there will be produced a change of magnetic moment just as if the body were diamagnetic. This effect will, however, be masked by what occurs after a very brief time. Just as a dipping needle will set its axis of magnetic moment along the direction of the earth's field, so will the atom strive to set the axis of its resultant magnetic moment along the direction of the applied magnetic field, and the atom will turn. If there were nothing to hinder, the atoms would line up with fine regularity, all the magnetic axes being parallel to each other and to the magnetic field, but this is not allowed to occur. The thermal agitation of the particles of matter will tend to undo any nice arrangement caused by the magnetic field. It will not succeed entirely, nor will the magnetic field. A compromise will be effected. A state of statistical equilibrium will be reached in which the same number of molecules per cubic centimetre will always have their axes in a specified direction, though this fixed number will not be made up of the same molecules at two different times. If the substance is a ferromagnetic solid, another cause will intervene to prevent the alignment of the atomic axes,—to-wit, the mutual effect of one atom on the other. This is of great importance, but its consideration must be deferred. It may be well to sum up what seem to be the distinguishing marks of the three magnetic states of matter. Diamagnetic substances consist of atoms having no resultant magnetic moment. Paramagnetic and ferromagnetic substances have atoms possessing a resultant moment. In ferromagnetic substances interaction between atom and atom or molecule and molecule plays a predominating part.

Let us revert to paramagnetic substances. When the external field is brought to bear upon them, first each atom experiences a change of moment producing a diamagnetic effect. This is followed by a turning of the atom so as to put its magnetic axis more closely in line with the lines of force of the magnetic field. Let us suppose that there is no thermal motion nor interatomic force to interfere; that is, let the experiment be made with a perfect gas at absolute zero of temperature. All the atoms would be in line and the substance would have the greatest magnetic moment per gramme possible for it to have. If heat were applied so that the temperature should rise, some of the atoms would get out of alignment and the magnetic moment and consequently the susceptibility would grow less. The application of a stronger field would tend to bring back the atoms to line and thus increase the moment. These elementary considerations show that as temperature goes up susceptibility goes down, and that magnetic moment and field strength increase together. These results are at least consistent with Curie's statement that the susceptibility of some paramagnetic substances is independent of the field strength and inversely proportional to the absolute temperature.

Langevin, however, goes much further than such a general agreement. He deduces an equation for a paramagnetic gas connecting intensity of magnetization, temperature, and strength of field. For field strengths from zero to those enormously greater than any we can now produce this equation shows the intensity proportional to field strength, that is, the susceptibility to be constant while the temperature is constant, and also the susceptibility to vary inversely as the temperature. Note that this derivation holds for a gas or for a dilute solution and not for solids and liquids in general. Before Langevin, DuBois deduced Curie's law that susceptibility is inversely as the absolute temperature from theoretical considerations. There can be no doubt that Langevin advanced magnetic theory greatly, though he left much unexplained.

Ferromagnetic substances differ from paramagnetic ones in these respects: they are capable of being magnetized so as to have a very much greater magnetic intensity than the latter ever have; they form permanent magnets, and their present magnetic state depends on their past magnetic history. Their comportment with regard to magnetic forces is characterized by an almost total lack of the simplicity which marks both diamagnetic and paramagnetic bodies. It remained for Pierre Weiss, now professor in the Federal Polytechnikum in Zürich, to unravel in part the mysteries of their behavior. Professor Weiss has, I believe, done more than any other living man to make clear the physiology and anatomy of the magnet. In 1907 a committee of the French Academy of Science, consisting, among others, of Mascart, Lippmann, Becquerel, Amagat, Violle, and Poincaré, awarded him the Kastner-Boursault prize, and in the present year he has become the recipient of the Lasferre prize of $1600.

FIG. 6.

PIERRE WEISS.

Weiss's method of attacking the problem of ferromagnetic substances is to extend to them the theory which Langevin had framed for paramagnetic bodies. To do this he supposes that there is within a ferromagnetic substance everywhere and at all times, when it is magnetized as a whole, a magnetic field due to the influence of the adjacent elementary magnets. This field does not manifest itself outside of the substance because there the distance from the centres of force is too great, and this force, unlike gravity and other forces, decreases not inversely as the square but as the sixth power of the distance. This last relation Weiss deduces on the supposition that the action proceeds from one point in a molecule and not from two points or poles in the same molecule.

He assumes the molecular field, as he calls it, to have a strength proportional to the intensity of magnetization of the material and to be in the same direction. When a piece of iron is put in a magnetic field there is within it a total field whose strength is the sum of the imposed field and of the molecular field.

The process of magnetizing a piece of steel would probably be about as follows: To begin with, each atom is a magnet because of the motion of its electrons. Each atom experiences a magnetic field coming from its neighbors, but from atom to atom these molecular fields change in direction, being distributed according to the laws of chance. Let the steel be placed in the middle of a coil of wire traversed by a current. The imposed magnetic field causes the atoms of steel to turn so that their magnetic axes are as nearly in line with the direction of the external magnetic field as their thermal agitation will permit. When the atoms turn into line the "molecular field" emanating from them does the same. Let the current in the magnetizing coil cease. The molecular field within the steel will retain a considerable part of its former value. The atoms will thus remain in at least partial alignment under the action of their mutual forces. This explanation of permanent magnetism is close to that given by Ewing.

Though as yet there seems no way of directly measuring the strength of this molecular field, it can be calculated and enormous magnitudes are obtained, no less than 17,300,000 gausses for magnetite and 3,030,000 for Fe^2Ni respectively. Weiss has examined the possibility of such enormously strong fields arising from rotating electrons in atoms. He concludes that it is impossible. It may be this which has led him to revise his conception of the molecular field. In 1914 he writes: "It is convenient to represent the mutual actions between molecules which come in play in magnetic phenomena as being themselves magnetic. This is, however, by no means necessary. Whatever may be their nature, the effects would be the same,"—under a certain proviso. He proceeds to argue that the actions are neither magnetic nor electrostatic in character, and frankly acknowledges that the nature of the force is as yet unknown. Even in spite of this limitation in our knowledge of it, Weiss says: "The hypothesis of the molecular field has shown itself fertile. At once this field, joined to the external magnetic field, permits us to derive the strong magnetization of ferromagnetic substances from the laws of paramagnetism alone. This is not without analogy with the properties of fluids, translated by the theory of Van der Waals, where the great density of liquids is derived from the properties of gases by means of the interior pressure which comes to join itself to the pressure from outside. Just as a liquid can exist under zero external pressure, and even under a negative pressure,—that is to say, under the internal pressure alone,—so can a ferromagnetic body be strongly magnetized by the molecular field alone in the absence of any external field. . . . The molecular field has given for the first time a theoretical deduction of the law of the thermal variation of magnetization at saturation. . . . The conception of the molecular field leads to an easily verifiable law for the magnetization of ferromagnetic substances above the Curie point." This last statement is of special interest. A hypothesis is surely valuable when it leads to the discovery of a hitherto unsuspected law. This is the law: the specific susceptibility of a ferromagnetic substance at any temperature above the Curie point, multiplied by the excess of that temperature above the Curie point, gives a constant. For a considerable number of ferromagnetic substances studied, including both metals and alloys, this relation has been found to hold. The mineral pyrrhotine and gamma iron are exceptions.

The constant product obtained as above indicated is found to be related to the moment of a single molecule in just the same manner as the Curie constant is related. Hence it also may be called by the same name.

By using the theory of the molecular field Weiss has been able to explain why it is that the specific heat of ferromagnetic substances suffers an abrupt change in amount at their Curie points. In a permanent magnet the atoms are in such positions that their potential energy due to mutual attractions and repulsions is a minimum. If an atom be rotated slightly it will be necessary to do work against the restraining forces. This is confirmed by the fact that the impartation of heat energy to a magnet causes its magnetic intensity to grow less, due, we believe, to a change in the alignment of its molecules. The specific heat of the substance may be regarded as made up of two parts, one characteristic of the substance and the other due to the molecular field within it. The enormous value of the molecular magnetic field makes this second term in the sum of the same order of magnitude as the specific heat itself. It can be shown that the energy which a magnetized body has is proportional to the square of its intensity. The specific heat due to magnetization will then be proportional to the change in the square of the intensity caused by a change of 1° in temperature. As the temperature rises and approaches the Curie point this change in the square of the intensity becomes greater and greater, and the specific heat due to magnetism grows correspondingly greater. Since the molecular field disappears when the Curie point is reached, there will be a marked difference between the specific heat above that point and below it. The following table [2] contains some data for iron calculated from Curie's experimental results. The first column gives the temperature of the iron, the second its specific intensity, the third, the number of calories absorbed for magnetic effects per gramme in raising the temperature from the stated temperature to the Curie point, the fourth, the specific heat in calories due to magnetic effects, and the last column the temperature interval for which the specific heat was measured.

t° C.	$\frac{I}{D}$ C.G.S.	Cal.	Cal.	In the interval.
20	216.3	16.8	.005	20°–275°
275	207.5	15.5	.013	275°–477°
477	189.6	12.9	.027	477°–601°
601	164.0	9.7	.045	601°–688°
688	127.0	5.8	.068	688°–720°
720	100.7	3.6	.108	720°–740°
740	64.	1.5	.136	740°–744.6°
744.6	50.1	.9		
753.	0 (by extrapolation)			

It is possible to locate the Curie point both by magnetic and by thermal experiments, and to determine the difference between the specific heats just above and below the Curie point in the same two ways. The following table shows an excellent agreement between the results of the two methods of determination:

---

[2] E. H. Williams, "The Electron Theory of Magnetism," p. 54.

	By magnetic measurements.	By heat measurements.
Iron.		
Discontinuity	.136 cal.	.112 cal.
Curie point	753° C.	758° C.
Nickel.		
Discontinuity	.025 cal.	.027 cal.
Curie point	376° C.	376° C.
Magnetite.		
Discontinuity	.048 cal.	.050 cal.
Curie point	588° C.	580° C.

THE MAGNETON.

Following the ideas of Ampère and Weber, we have considered the individual atom as having magnetic poles and, in consequence, a magnetic moment. This "molecular moment" (as it will here be called, in accordance with the practice of P. Weiss, though "atomic moment" might be a more logical designation) is a quantity of considerable interest. How can it be measured?

Let us suppose ourselves endowed with eyes and fingers adequate for the task of handling single atoms. Let us take a thousand of them and arrange them in a row, with all the north poles toward the same side. This would mean that the north pole of one atom would lie next to the south pole of the adjacent atom. Since these two poles are of equal strength and very close together, they will neutralize each other for points a little distance away. The north pole at one end of the row and the south pole at the other end, however, are not so neutralized. The magnetic moment of the row is equal to the strength of one of the uncompensated poles at the end multiplied by the length of the row,—that is, by 1000 times the length of one atom. The moment of a single atom is the strength of one of its poles multiplied by the distance from pole to pole, or the length of the atom. The magnetic moment of the row of 1000 atoms will be 1000 times as large as the moment of a single atom, because the pole strength is the same in calculating both quantities, while the distance from pole to pole is 1000 times as long in the row as in the single atom. We see then that if we can take a very large number of atoms and line them up and keep them from getting out of line by reason of heat agitation we will be able to measure the magnetic moment of the resultant body of tangible size. The moment of the single atom can then be calculated by dividing the total moment by the number of atoms in the body.

An impressed magnetic field will bring about the alignment, and a reduction of temperature will do away with disturbance of the arrangement by heat. In more technical language, the phenomena of magnetic saturation at the absolute zero must be studied. In 1910 Kamerlingh Onnes and Weiss made public the result of their studies of several ferromagnetic substances almost under the conditions just specified. They gave the magnetic moments per gramme atom,—that is, for a quantity of the substance whose mass is one gramme multiplied by the atomic weight of the substance. A gramme-atom of an element has the same number of atoms in it, no matter what the element is. They found the magnetic moment of iron per gramme atom to be 12360 (C.G.S.), and of nickel 3370. If the first of these numbers be divided by 11 the quotient is 1123.6. The second divided by 3 gives practically the same quotient, 1123.3. If we compare a mass of iron saturated at very low temperature with a mass of nickel having in it as many atoms as there were in the iron it will be found then that the iron has a moment $\frac{11}{3}$ as great as the nickel, and hence that the iron atom has a magnetic moment $\frac{11}{3}$ as great. There are 68×10^{22} (*i.e.*, 68 followed by 22 ciphers) atoms in one gramme-atom. Divide the moment of a gramme-atom of iron by the number of atoms in it and the quotient is 181.7×10^{-22}. This is the magnetic moment of one iron atom. By a like division the same quantity for a nickel atom is found to be 49.5×10^{-22}. The greatest common divisor of these quantities, which goes 11 times into the first and 3 times into the second, is 16.5×10^{-22} (C.G.S.). To this quantity of magnetic moment Weiss, in 1911, gave the name "magneton." About six months previously L. A. Bauer, the director of the Department of Research in Terrestrial Magnetism of the Carnegie Institution, had used the word in a different sense.

The investigators were unable to saturate cobalt magnetically and thus obtain its magnetic moment per atom. By an indirect method,—that is, by studying the moment at saturation of nickel-cobalt alloys of varying composition,—Bloch found the moment of the cobalt atom to be 8.925 magnetons, while Preuss got from the study of iron-cobalt alloys the value 8.97 magnetons. Another interesting result of Preuss's work is the discovery of an iron-cobalt compound, 34 per cent. Co + 66 per cent. Fe, Fe^2Co, which is more magnetic than iron to the extent that at ordinary temperatures its intensity of magnetization exceeds that of iron by 10 per cent. When Weiss used less than one kilogramme of this material to make pole pieces for his electromagnet he got a field of 55,170 gausses, whereas under like conditions with iron pole-pieces the field was only 52,580 gausses. When the electromagnet was energized by a power of 5.5 kilowatts with the new pole pieces the same field was obtained as with four times as many kilowatts and the iron pieces.

For the determination of the atomic moment at high temperatures there is fortunately a simple relation between this quantity and the Curie constant.

Nickel has been well studied. It has been found to exist in two states: β_1 nickel from 370° to 900° with eight magnetons per atom, and β_2 nickel above 900° with nine magnetons per atom. The following table sums up the work done on this element:

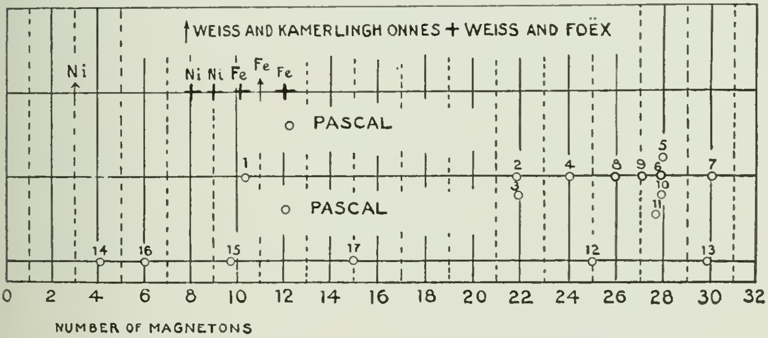
Experimenter	Substance	Number of magnetons per atom
Weiss and Foëx	Ni.β_1 directly	8.03
Bloch	Ni.β_1 directly	7.99
Renker	Ni.β_1 directly	8.04
Renker	Ni.β_1 study of ferronickels	8.05
Weiss and Foëx	Ni.β_2 study of ferronickels	9.03
Bloch	Ni.β_2 directly	8.96
Renker	Ni.β_2 directly	8.93
Renker	Ni.β_2 study of ferronickels	8.96
Bloch	Cobalt directly	15.01
Preuss	Cobalt directly	14.99
Weiss and Foëx	Iron β_1 directly	12.08
Renker	Iron β_1 directly	11.98
Renker	Iron β_1 study of ferrocobalts	11.97
Weiss and Foëx	Iron β_2 directly	10.04
Preuss	Iron β_2 directly	10.00
Renker	Iron β_2 directly	10.05
Renker	Iron β_2 study of ferrocobalts	10.10
Preuss	Iron β_2 study of ferrocobalts	20.05
Renker	Iron β_3 study of ferrocobalts	20.20

In this diagram the vertical lines are drawn one magneton apart. The circles and arrows indicate by their position horizontally the number of magnetons in the molecule of the substance. It is to be noted how often the circles come on the vertical lines and how rarely they miss them.

A study of magnetite shows that it exists in five states in which the molecular moments are in the relation 4 : 5 : 6 : 8 : 10, but seem not to be exact multiples of the magneton. Even in the case of solid paramagnetic salts the atomic moment keeps close to whole multiples of the magneton.

From considerations based on its specific heat it seems essential to conclude that the oxygen molecule is rigid and has only a single magnet. Its moment is found to be 14.014 magnetons. For the molecule of NO the moment is 9.039 magnetons.

FIG. 7.



1–11. Various salts of iron.
12. Cobalt chloride.
13. Manganese sulphate.
14. Permanganate of potassium.
15. Cupric sulphate.
16. Cuprammonium sulphate.
17. Uranous sulphate.

The same atom seems capable of having very different magnetic moments according to its temperature and associates within the chemical molecule; *e.g.*, near the absolute zero a nickel atom has a moment of three magnetons, above 400° it has eight, above 900° it has nine, while in solutions of its salts it has sixteen.

Weiss says: "If we admit, what is extremely probable, that the magnetic moment resides in a material substratum, we can say that the magneton is a constituent element of a great number of magnetic atoms and probably of all. So far proof has been made for Fe, Ni, Co, Cr, Mn, V, Cu, U. . . . The magneton idea furnishes a new point of attack on magnetic problems. The parallelism of intensity of chemical properties with the number of magnetons raises new questions. What rôle do the magnetic phenomena play in chemical combination? Are chemical forces in certain cases the attraction of elementary magnets? Does valence stand in any relation to the magneton? . . . The magneton is a third constituent of matter which, like the electron and the alpha particle, belongs to a great number of molecules. Antiquity believed in the unity of matter. The alchemists in seeking to make gold endeavored to transform this belief into tangible reality. . . . Now the discovery of constituents common to all atoms brings us anew to the conception of the Greeks and to the Unity of Matter." He suggests that his magneton may be one of the constituent elementary magnets which Ritz imagines arranged in neat rows with electrons revolving about them in order to explain the orderly series of spectral lines emitted by the atom.

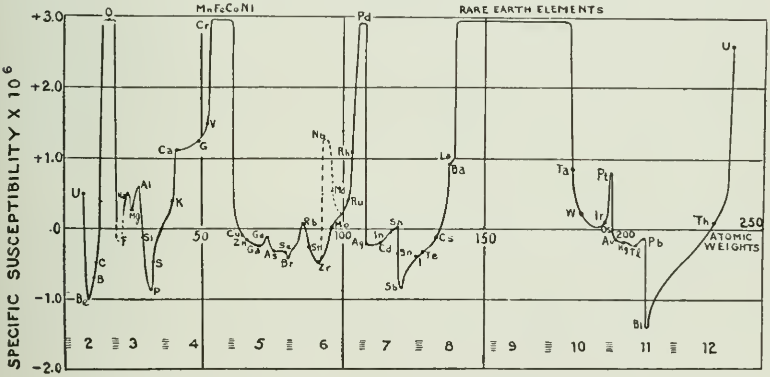
It is a logical sequence which leads from the definition of the magneton as a quantity to its recognition as a separate entity. A study of the weight of Philadelphia chimneys would show that all the weights have a greatest common divisor, but it would not be long before the investigator would conclude that this particular weight is associated with some individual piece of matter, and the conception of a brick would be forthcoming.

Can the magnitude of the magneton be accounted for by supposing it due to one electron revolving in an atom? The magnetic moment of such an electron orbit can be calculated from a knowledge of three other quantities: the electric charge of the electron, the area of its orbit, and its time of revolution. When these are substituted in the formula for the moment a quantity is obtained equal to about one-tenth of the magneton. It is significant that they are not very different in magnitude.

Gans and Weiss have attacked magnetic problems from different sides. Weiss postulated a molecular field and arrived at the conception of the magneton. Gans, on the other hand, starts from a study of elementary magnets and their groupings and deduces a law for the susceptibility of ferromagnetic substances which is equivalent to that found by Weiss. It strengthens our confidence in this law that it has been derived independently by two different investigators following diverse methods.

Much interest attaches itself to investigations of magnetic properties at low temperature because the motion due to heat plays a less and less important part as the absolute zero is approached. The idea had occurred that those three metals, vanadium, chromium, and manganese, which lie next to the strongly magnetic group, iron, nickel, and cobalt, might, like these, be really magnetic, but have their Curie point so far below ordinary temperatures that they behave as paramagnetic, just as iron acts at high temperature. Onnes and Weiss investigated this possibility, but they found no trace of ferromagnetism in vanadium and chromium. Manganese was paramagnetic, but after having been fused it was ferromagnetic.

FIG. 8.



Gadolinum sulphate faithfully followed Curie's law that specific susceptibility is inversely as the absolute temperature even down to 17° absolute. At the melting-point of hydrogen it deviates slightly. At 290.3° absolute its specific susceptibility is proportional to 73, while at 13.91° absolute it has grown to 1468.

Oxygen is of peculiar importance for magnetic investigations, because as a gas it is paramagnetic, while most other gases are diamagnetic, and, besides, it can be worked with in the solid, the liquid, and the gaseous state. Curie showed that from 20° C. to 452° C. gaseous oxygen follows his law. Onnes and Oosterhuis found that it continues to do this down to about 170° absolute. Liquid oxygen does not follow Curie's law that the product of absolute temperature and specific susceptibility is constant. It does, however, admit the relation that the square root of the absolute temperature multiplied by the susceptibility is constant. This relation holds from 90° to 65° absolute. Solid oxygen has a much lower susceptibility than the liquid. When the liquid freezes the susceptibility drops to about one-third, then as the temperatures reaches – 240° C. another drop to one-half occurs in the susceptibility.

Any explanation of magnetic phenomena at low temperatures is complicated by the approach of the molecules to each other and by our ignorance as to whether any energy remains in matter at the absolute zero.

Let me call your attention to a curve showing the connection between specific susceptibility and atomic weight. Notice the periodic change from positive to negative susceptibility, the change, that is, from paramagnetic to diamagnetic. Take the sodium group, lithium, sodium, potassium, rubidium, cæsium, with atomic weights 7, 23, 39, 85, 133, and note their position. There is a fall in susceptibility with increasing atomic weight. While the curve is by no means smooth and regular, it certainly indicates a connection of a periodic character between the two quantities it represents.

At this point I cease my discussion of modern investigations in magnetism. It is not possible to give any impression save that of incompleteness, for the work is by no means finished. The problem of the reality of the magneton must be decided, and this conception must either be relegated to the limbo where dwell such cast-off terms as caloric, the N rays, hot ice, and the emission theory of light, or, with the electron, the alpha, beta, and gamma rays, be accepted as members in good standing of physical society. Who would want to serve a science that is finely rounded and complete, with no questions lacking an answer, with no phenomena waiting for explanation? Such a science might be beautiful, symmetrical, logically perfect, but it would also be dead.

(NOTE.—The writer desires to make his acknowledgments to a number of authors for diagrams and other material employed in the above paper.)

NORTHEAST HIGH SCHOOL,
Philadelphia.

STANDARDIZED COLORED FLUIDS.[1]

BY

H. V. ARNY, Ph.D.,
Professor of Chemistry, Columbia University College of Pharmacy,
Member of the Institute,

AND

C. H. RING.

This is the fifth of a series of papers [2] on the subject of color standardization, the work being begun by one of us in connection with his duty as chairman of a sub-committee of the Committee on Revision of the National Formulary, to which was entrusted the task of obtaining reliable and definite standards for the various coloring agents—notably cudbear and caramel—for which recipes are provided in that book. In pursuing this investigation, there was devised a plan of color standardization which afforded a simple and practical way of establishing color standards.

As fully explained in the paper read before the Eighth International Congress of Applied Chemistry, the idea of preparing any shade of color by blending permanent standardized colored fluids of red, yellow, and blue appealed to him; and, as reported at that congress, the first set of such colored fluids was prepared by making half-normal solutions of cobalt, ferric iron, and copper. From these solutions were prepared the 88 blends, representing all the possible combinations in a total volume of 12 Cc. of fluid, where the amount of each of the three ingredients ranged from 1 to 12 Cc., fractional parts of the cubic centimetre being avoided.

The idea of using solutions of colored metallic salts for matching tints has already been employed in water analysis by Crookes, Odling and Tidy, and by Hazen; but the plan mentioned above has the following points of originality:

---

[1] Communicated by Dr. Arny.

[2] "Color Standards," by H. V. Arny, *American Druggist,* 60 (1912), 35. "International Standards for Colored Fluids," by H. V. Arny, *Proceedings of the Eighth International Congress of Applied Chemistry* (1912), 26, 319. "Weiteres über Normal Farben," by H. V. Arny, *Deutsch-Amerikanische Apotheker Zeitung,* 33 (1913), 165. "The Problem of Color Standardization," by H. V. Arny and E. G. Pickhardt, *Druggists' Circular,* 57 (1914), 131.

First.—The cobalt, iron, and copper solutions are prepared as definite volumetric solutions of half-normal strength.

Second.—The blending of these in any proportion to a constant volume insures the widest possible range of tints.

It was found that in blends of the *neutral* (unacidulated) half-normal solution precipitation occurred within a few days after preparation; so, in subsequent work, *acidulated* solutions of half-normal strength were used, the solvent being a diluted hydrochloric acid made from 25 Cc. of concentrated (30 per cent.) acid and 975 Cc. of water.[3] This modified the tints of the original solutions and the blends, but not enough to seriously affect the value of the fluids as standard colors, which were thus made practically permanent.

This line of colors, which we called the "*Co-Fe-Cu*" tints, was fully described in the *Druggists' Circular* for March, 1914, and in that article it was frankly stated that the value of these tints was lessened through the fact that the cobalt solution did not furnish a sufficiently pure red color. In short, while the "Co-Fe-Cu" blends furnished an ideal line of green, yellow, and orange tints, they lacked in deep reds and dark blues.

During the past year we have been able to pursue the problem to a successful issue by preparing a line of ammoniacal fluids which furnish most of the necessary tints.

This line, which we call the "Co-Cro-Cu" fluids, was made up as follows:

Red tenth-normal ammoniacal cobalt solution was prepared by dissolving 13.5 grammes of roseo-cobaltic-chloride ($CoCl_3$ $5NH_3.H_2O$) in enough of a fluid consisting of 100 Cc. of 28 per cent. ammonia water and 900 Cc. of water to make a litre of finished product.[4]

---

[3] Since this strength of acid was used throughout our work, since it was made up empirically, and since its approximate strength is about 1 in 100, we will in future speak of it as 1 per cent. hydrochloric acid.

[4] The tenth-normal and fiftieth-normal solutions here described are based on the absolute amount of metal contained in each. As cobalt has the atomic weight 58.97 and a valence of 2, we assume that a tenth-normal cobalt solution will contain 2.9485 Gm. of the metal per litre and that the fiftieth-normal will contain one-fifth of this amount. As copper has the atomic weight 63.57 and the valence is 2, we assume that a tenth-normal copper solution will contain 3.1785 Gm. of the metal to the litre and that the fiftieth-normal will contain one fifth of this amount. As chromium has the atomic weight 52.00

The solution thus prepared was then assayed gravimetrically and so diluted that each cubic centimetre of fluid contained 0.0029485 Gm. of metallic cobalt. Experience showed, however, that empiric solutions prepared by dissolving 13.43 Gm. of the roseo-cobaltic chloride in a diluted ammonia of the strength just stated did not vary sufficiently from the standard in color intensity to make assay necessary in average work.

If the commercial roseo-cobaltic chloride is not obtainable, it can be prepared as follows: Dissolve 12 Gm. of cobalt chloride ($CoCl_2 6H_2O$) in about 100 Cc. of water. After filtration, add 100 Cc. of 28 per cent. ammonia, shake well, and keep in a warm place (between 50° to 70° C.) six or eight hours, with occasional shaking. Let stand over night at ordinary room temperature. Warm again at same temperature as before and gradually dilute with water, a small portion at a time in such a way that the temperature of the liquid will not go below 50°, until it has been diluted to 1 litre. We now have an empiric tenth-normal ammoniacal cobalt chloride of a bright red color. This solution shows a yellow tinge when examined closely and therefore cannot be used as a standard. But from it the roseo-cobaltic salt can be made by the addition of an excess of concentrated hydrochloric acid and then boiling for several minutes until a precipitate forms. The precipitation can be hastened by chilling with running water. The precipitate collected on a filter is washed with 1 per cent. hydrochloric acid and is then dried in oven at about 100° C.

Yellow tenth-normal ammoniacal chromium solution was made by dissolving 3 Gm. of ammonium dichromate ($(NH_4)_2Cr_2O_7$) in 50 Cc. of 1 per cent. hydrochloric acid, then adding 50 Cc. of 28 per cent. ammonia water, and finally diluting with enough water to make one litre. The solution was then assayed gravimetrically and so diluted that each cubic centimetre of fluid contained 0.0008666 Gm. of chromium. It was found, however, that by making an empiric solution of 2.1 Gm. of ammonium dichromate

---

and presumably has the valence 6 in the dichromate, then a tenth-normal solution will contain 0.8666 Gm. of chromium to the litre and a fiftieth-normal will contain one-fifth of this amount. This conception of fiftieth-normal chromium is quite different from the commonly-accepted term, tenth fiftieth or hundredth-normal dichromate solution used in the oxidizing titrations; in which case, as is well known, the titre of the solution is based on its oxygen-producing capacity, rather than its absolute chromium content.

dissolved in 1 per cent. hydrochloric acid and then adding 28 per cent. ammonia water and diluting with water to 1 litre the color value was the same as that of the standardized solution.

Blue tenth-normal ammoniacal copper solution was prepared by diluting 200 Cc. of standard assayed half-normal copper sulphate (containing 62.43 Gm. of $CuSO_45H_2O$ to the litre) to tenth-normal alkaline fluid, by adding 100 Cc. of 28 per cent. ammonia water and then making up to 1 litre with water. Each cubic centimetre of this solution contained 0.0031785 Gm. of metallic copper.

As with the other fluids, a carefully-prepared empiric solution gave the same color value as the assayed standard.

Assayed standard half-normal solutions of both copper sulphate and copper chloride were prepared. Each was diluted to tenth-normal ammoniacal copper in the manner just outlined and the two blue colors compared. They were practically identical both in tint and intensity of color. In making empiric copper solution, however, only perfect crystals of chemically pure copper sulphate were used.

Further data concerning these three standard solutions will be found below. At this place we will merely point out that for ordinary purposes of comparison we found the blends prepared from these tenth-normal ammoniacal solutions were too dark. We therefore diluted them down with water to equal fiftieth-normal solutions, and from these latter we prepared the " Co-Cro-Cu " blends.

COMPARISON OF STANDARD TINTS.

When starting on the investigation of which this paper is a part, the first difficulty encountered was the lack of an accurate and available basis of comparison for fluid colors. Of course, the solar spectrum itself was the first standard thought of, and one of us, with Dr. H. H. Schaefer, spent some weeks during 1913 attempting to match our colored fluids against this natural standard. But like other investigators, we found that the very brilliancy of the spectrum colors was a drawback, and that our colored fluids, attractive though they were, paled before the glory of a spectrum segment. We still hope, however, that we may yet be able to devise some scheme whereby our colors can be expressed in terms of solar tints.

Finding, for the time being, this ideal plan futile, we turned to that interesting color apparatus, the Lovibond tintometer, which, as was explained in the *Druggists' Circular* article cited above, possessed the advantages of simplicity, permanency, and availability. Another of its advantages for our work was that the colors of the glass slides used in the tintometer were not superior to the tints of our standard colored fluids.

In the article just referred to, the Lovibond readings of the acidulated half-normal (red) cobalt, (yellow) ferric iron, and (blue) copper solutions were given, as well as similar readings of the 88 blends already mentioned.

During the past winter Lovibond readings of the "Co-Cro-Cu" blends have been made, and the results are tabulated below:

Lovibond Readings of the Tenth-Normal Standard Ammoniacal Solutions in a ¼-inch Cell.

Note.—In this and all other Lovibond readings in this paper, the red Lovibond glasses were No. 200, the yellow were No. 510, and the blue were 1180.

$$\text{Roseo-Cobaltic Chloride} \ldots \left\{\begin{array}{l} \text{Red} = 5.0 + 4.0 + 3.0 + 2.0 + 1.9 + 1.8 + 1.6 = 19.3 \\ \text{Yellow} = -0.7 \\ \text{Blue} = -1.6 \end{array}\right.$$

$$\text{Ammonium Dichromate} \ldots \left\{\begin{array}{l} \text{Red} = -0.3 \\ \text{Yellow} = 5.0 + 4.0 + 0.4 = 9.4 \\ \text{Blue} = \text{None} \end{array}\right.$$

$$\text{Copper Sulphate} \ldots\ldots\ldots\ldots \left\{\begin{array}{l} \text{Red} = -4.0 \\ \text{Yellow} = \text{None} \\ \text{Blue} = 5.0 + 4.0 + 3.0 + 2.0 + 1.9 + 1.3 = 17.2 \end{array}\right.$$

Fiftieth-Normal Standard Ammoniacal Solution in ½-inch Cell.

$$\text{Roseo-Cobaltic Chloride} \ldots \left\{\begin{array}{l} \text{Red} = 5.0 + 3.0 + 0.2 = 8.2 \\ \text{Yellow} = \text{None} \\ \text{Blue} = -0.4 \end{array}\right.$$

$$\text{Ammonium Dichromate} \ldots \left\{\begin{array}{l} \text{Red} = \text{None} \\ \text{Yellow} = 5.0 + 1.0 + 0.4 = 6.4 \\ \text{Blue} = +0.2 \end{array}\right.$$

$$\text{Copper Sulphate} \ldots\ldots\ldots\ldots \left\{\begin{array}{l} \text{Red} = \text{None} \\ \text{Yellow} = \text{None} \\ \text{Blue} = 5.0 + 1.0 + 0.4 = 6.4 \end{array}\right.$$

Total Lovibond Readings of the Fiftieth-Normal Standard Ammoniacal "Co-Cro-Cu" Blends in ½-inch Cell.

Co-Cro-Cu	Red	Yellow	Blue
12 – 0 – 0	5.0 + 3.0 + 0.2	None	– 0.4
11 – 1 – 0	5.0 + 1.9	0.7	– 0.4
10 – 2 – 0	5.0 + 1.5	1.5	– 0.4
9 – 3 – 0	5.0 + 0.7	2.0 + 0.4	– 0.3
8 – 4 – 0	5.0 + 0.1	3.0	– 0.3
7 – 5 – 0	3.0 + 1.5	2.0 + 1.6	– 0.3
6 – 6 – 0	4.0	4.0	– 0.2
5 – 7 – 0	3.0	4.0 + 0.2	– 0.2
4 – 8 – 0	2.0	4.0 + 0.4	– 0.2
3 – 9 – 0	1.0 + 0.4 + 0.1	5.0	– 0.2
2 – 10 – 0	0.7 + 0.2	5.0 + 0.4	– 0.1
1 – 11 – 0	0.4	6.0	None
0 – 12 – 0	None	5.0 + 1.0 + 0.4	+ 0.2
0 – 11 – 1	None	4.0 + 1.6	0.4 + 0.1
0 – 10 – 2	None	5.0	1.0 + 0.2
0 – 9 – 3	None	4.0 + 0.2	1.0 + 0.4
0 – 8 – 4	None	3.0 + 0.7 + 0.1	2.0
0 – 7 – 5	None	3.0 + 0.2	2.0 + 0.2 + 0.1
0 – 6 – 6	None	3.0	3.0 + 0.2
0 – 5 – 7	None	2.0 + 0.2 + 0.1	3.0 + 0.4 + 0.2
0 – 4 – 8	None	1.9	4.0 + 0.1
0 – 3 – 9	None	1.6	4.0 + 0.7
0 – 2 – 10	None	1.0	5.0 + 0.2
0 – 1 – 11	None	0.4 + 0.1	5.0 + 0.7
0 – 0 – 12	None	None	5.0 + 1.0 + 0.4
1 – 0 – 11	0.7	None	5.0 + 0.7
2 – 0 – 10	1.3 + 0.1	None	5.0
3 – 0 – 9	2..0 + 0.1	None	4.0 + 0.2
4 – 0 – 8	2.0 + 0.7	None	3.0 + 0.7
5 – 0 – 7	3.0 + 0.4 + 0.2	None	3.0 + 0.2
6 – 0 – 6	4.0 + 0.2	None	2.0 + 0.4
7 – 0 – 5	3.0 + 1.9	None	1.8
8 – 0 – 4	5.0 + 0.7	None	1.3 + 0.1
9 – 0 – 3	5.0 + 1.3	None	0.7 + 0.1
10 – 0 – 2	5.0 + 1.6	None	0.2 + 0.1
11 – 0 – 1	5.0 + 2.0 + 0.3	None	– 0.1
10 – 1 – 1	5.0 + 1.0	0.7	None
9 – 2 – 1	5.0 + 0.7	1.5	None
8 – 3 – 1	5.0	2.0 + 0.1	None
7 – 4 – 1	4.0 + 0.2 + 0.1	2.0 + 0.2	None
6 – 5 – 1	3.0 + 0.4 + 0.1	1.5 + 1.0	None
5 – 6 – 1	3.0	3.0	None
4 – 7 – 1	2.0	2.0 + 1.5 + 0.1	None
3 – 8 – 1	1.6	4.0 + 0.1	None

Co-Cro-Cu	Red	Yellow	Blue
2- 9- 1	0.7 + 0.2	4.0 + 0.7	None
1-10- 1	0.2	5.0 + 0.2 + 0.1	None
1- 9- 2	None	4.0 + 0.4	+ 0.7
1- 8- 3	None	2.0 + 1.6	1.3
1- 7- 4	None	3.0 + 0.2 + 0.1	1.8
1- 6- 5	None	1.6 + 1.0	2.0 + 0.4
1- 5- 6	None	2.0 + 0.2 + 0.1	3.0
1- 4- 7	None	2.0	2.0 + 1.8
1- 3- 8	None	1.5	3.0 + 1.3
1- 2- 9	None	1.0 + 0.1	3.0 + 1.9
1- 1-10	None	0.7	5.0 + 0.4 + 0.1
2- 1- 9	0.2	0.4	4.0 + 0.7
3- 1- 8	1.0	0.2 + 0.1	3.0 + 0.4 + 0.2
4- 1- 7	1.9	0.2 + 0.1	3.0
5- 1- 6	2.0 + 0.4	0.4	2.0 + 0.1
6- 1- 5	3.0 + 0.4	0.4	1.6 + 0.1
7- 1- 4	4.0 + 0.1	0.4	1.0 + 0.2
8- 1- 3	5.0	0.4	0.7
9- 1- 2	5.0 + 0.7	0.4	0.1
8- 2- 2	3.0 + 1.6	0.7	0.1
7- 3- 2	4.0 + 0.1	1.3 + 0.1	0.1
6- 4- 2	3.0 + 0.4	1.5	0.2
5- 5- 2	2.0 + 0.2	2.0 + 0.2 + 0.1	0.1
4- 6- 2	1.9	1.8 + 1.0	0.4 + 0.1
3- 7- 2	1.0 + 0.1	3.0 + 0.1	0.2
2- 8- 2	0.4	2.0 + 1.5	0.4
2- 7- 3	0.4 + 0.1	3.0	1.0
2- 6- 4	0.2	1.0 + 1.3	1.3
2- 5- 5	0.2	2.0 + 0.1	2.0 + 0.1
2- 4- 6	0.2	1.6	1.6 + 1.0 + 0.1
2- 3- 7	0.2	1.0 + 0.1	3.0 + 0.2
2- 2- 8	0.2	0.7	2.0 + 1.8
3- 2- 7	1.0 + 0.1	0.7	3.0
4- 2- 6	1.9	0.7	1.5 + 1.0
5- 2- 5	2.0 + 0.4	1.0	1.6 + 0.1
6- 2- 4	3.0 + 0.4	0.7 + 0.1	1.5
7- 2- 3	4.0 + 0.1	0.7	0.4 + 0.1
6- 3- 3	3.0 + 0.4	1.3	0.7 + 0.1
5- 4- 3	2.0 + 0.2	1.9	1.0
4- 5- 3	1.9	2.0 + 0.2 + 0.1	1.0
3- 6- 3	1.0	2.0 + 0.4 + 0.2	0.7
3- 5- 4	1.0	2.0 + 0.2	1.0 + 0.4
3- 4- 5	1.0	1.6	1.9
3- 3- 6	1.0	1.0 + 0.1	2.0 + 0.2
4- 3- 5	1.8	1.3 + 0.1	2.0 + 0.1
5- 3- 4	2.0 + 0.4	1.5	1.0 + 0.2 + 0.1
4- 4- 4	1.9	1.9	1.8

INTERPRETATION OF THE TABLES.

The foregoing tables give only a glimpse of the many interesting characteristics of these fluids and their blends.

In the first place, it is necessary to call attention to the fact that the glasses from which the Lovibond readings were obtained are so graduated that the color intensity of any red glass of a given number approximates the color intensity of a yellow glass or of a blue glass of that same number. This agreement is based on the fact that when three glasses, red, yellow, and blue, each having the same number, are superimposed and held to the eye in a good light, with a perfectly white perspective, a neutral gray tint is the result.

The numbers on the glasses represent units of color value. Thus the glass labelled " 0.1 " is supposed to have only one-tenth the color intensity of the glass labelled " 1.0," and therefore ten " 0.1 " glasses should match one " 1.0 " glass in color intensity. This principle holds good for all practical purposes when not more than three or four glasses are used at one time; but if ten " 0.1 " glasses, say of the yellow, were compared with one " 1.0 " yellow glass, the ten glasses would show a much darker effect, owing to the fact that there is ten times the thickness of plain glass to look through.

There are some blends of the glasses that do not match perfectly with other blends of supposedly the same total Lovibond value, even when each blend is composed of the same number of glasses, but these differences are very slight.

We have found that a reading, say Blue = 5.0 + 1.0 + 0.4, can, for all practical purposes, be considered as meaning 6.4 Lovibond color units, and can be matched, fairly closely, by any other combination of blue glasses that total 6.4 units. In the light of this statement it is interesting to note in the above table the following facts concerning the basic fiftieth-normal fluids:

The red fiftieth-normal ammoniacal cobalt solution shows a Lovibond value totalling 8.2 units of red, no yellow, and – 0.4 unit of blue.

The yellow fiftieth-normal ammoniacal chromate solution shows a Lovibond value totalling 6.4 units of yellow, no red, and 0.2 unit of blue.

The blue fiftieth-normal ammoniacal copper solution shows a Lovibond value totalling 6.4 units of blue, no red, and no yellow.

In the summary just given, and also in the tables, we find *minus* values. Thus the fiftieth-normal cobalt solution was so much purer red than the Lovibond glasses that, to secure a perfect match in tint, it was necessary to place 0.4 unit of blue glass in front of the cell containing the fluid when making the test.

The figures just given show that the total net color intensity of the three basic solutions—the red, the yellow, and the blue—is nearly equal when expressed in Lovibond units. Then, even as three Lovibond glasses, each of the same color value of red, yellow, and blue, give a neutral gray tint when combined, so equal volumes of the three fiftieth-normal ammoniacal color fluids should likewise give a neutral gray or almost colorless fluid when combined. This proves to be the case, with but a slight variation, owing to the fact that the cobalt standard solution has a little higher color value than either of the other two.

Still more interesting is the sequence of colors obtained when these three fiftieth-normal ammoniacal solutions are blended systematically. When each blend was put into a one-ounce Blake bottle, and the entire 88 blends, with a sample of each of the three standard solutions, were sorted by the eye, they fell naturally into five groups.

The first group, consisting of 36 samples, are pure spectrum colors, and represent the three fiftieth-normal standard colors, together with all the possible blends obtained by mixing any two of the three standards in cubic centimetre lots to a total volume of 12 Cc.

The second group consists of 27 hues, which are a trifle less bright than the first group. These represent all the possible blends obtained by mixing any two of the three standard fluids in cubic centimetre lots to equal a total volume of 11 Cc. and then adding to each blend 1 cubic centimetre of the odd standard fluid, making the entire volume of each blend equal 12 Cc.

The third group, consisting of 18 blends, is still less brilliant, and the blends here suggest a nearness to the neutral tint. They represent all the possible combinations obtained by mixing any two of the three standards in cubic centimetre lots to equal a total of 10 Cc. and then adding to each blend 2 Cc. of the odd standard, making the entire volume of each blend equal 12 Cc.

The fourth group, consisting of nine blends, is practically a group of neutral tints. These blends represent all the possible combinations obtained by mixing any two of the three standards in cubic centimetre lots to equal a total of 9 Cc. and then adding to each blend 3 Cc. of the odd standard, making the entire volume of each blend equal 12 Cc. Although the blends in this group are so near to neutral there is, in nearly each one, a sufficient preponderance of one of the three primary colors to give it its proper place in the system as a "neutral red," "neutral yellow," or a "neutral blue."

The fifth group consists of only one blend and contains an equal volume of each of the three fiftieth-normal ammoniacal standards. Theoretically this should be a perfect neutral gray, but owing to the fact that the standard red cobalt solution has a little greater color intensity than either the yellow or the blue, as will be seen in the table of Lovibond readings, this last blend of equal volumes shows a slight excess of red when observed closely.

When these five groups of 91 tints are arranged in a series of graduated circles, one inside another, in the mathematical order in which they appear in the table, an automatic sub-grouping of color effects that is produced is very interesting. The first group is the outer circle, and the blends are arranged from left to right in the same order that colors appear in the solar spectrum. Starting with blend "12 – 0 – 0," which is the pure red fiftieth-normal cobalt solution, we go from this through orange to yellow, then through green to blue, and then through violet back to red, blend "11 – 0 – 1" completing the first circle.

The second group of 27 blends is then arranged just inside the first circle, starting with blend "10 – 1 – 1," which takes its place under "12 – 0 – 0," and the circle is completed with blend "9 – 1 – 2."

The third group of 18 blends is now arranged inside of the second circle, starting with blend "8 – 2 – 2," which takes its place under "10 – 1 – 1," and the circle is completed with blend "7 – 2 – 3."

The fourth group is arranged in the same way inside of the third circle, blend "6 – 3 – 3" being placed under "8 – 2 – 2," and the circle ends with blend "5 – 3 – 4."

The fifth group, which is represented by only the one neutral equal volume blend, is now placed in the centre and forms what we may call the hub of the wheel. If this circular plat is appropriately subdivided into nine equal (40°) segments, we find that each segment contains a color group in itself.

THE PERMANGANATE-DICHROMATE BLENDS.

In reporting on the "Co-Fe-Cu" colored fluids and blends the limitations of the range of tints was frankly stated. The preparation of the ammoniacal line of "Co-Cro-Cu" fluids furnished us with the means of producing nearly every tint necessary to our needs. However, the pink, cardinal red, and a peculiar quality of violet color were not forthcoming.

As before stated, the "Co-Fe-Cu" fluids furnished practically every needed shade of orange, yellow, and green, while the "Co-Cro-Cu" line furnished the necessary blends in blue, bluish-red, and reddish-blue.

We have found that most of the tints which could not be obtained with either the "Co-Fe-Cu" or the "Co-Cro-Cu" line of colored fluids can be produced by blending proper proportions of a solution of potassium permanganate with a solution of potassium dichromate.

The permanganate solution is prepared by diluting the usual assayed tenth-normal volumetric solution to one-thousandth-normal strength so that each cubic centimetre contains 0.00001 Gm. of the element manganese. The yellow dichromate is prepared by diluting the usual assayed tenth-normal volumetric solution to one-hundredth-normal strength,[5] so that each cubic centimetre contains 0.00017 Gm. of the element chromium.

The Lovibond readings of these two standard solutions are here given:

One-Thousandth-Normal Potassium Permanganate in ½-inch Cell.

Red	Yellow	Blue
5.0 + 1.3	−0.7	+ 0.2

One-Hundredth-Normal Potassium Dichromate in ½-inch Cell.

Red	Yellow	Blue
0.3	5.0 + 2.0 + 0.1	− 1.0

These readings show that the intimation conveyed in the Chemical Congress article of the likelihood that equimolecular solutions of the colored fluids when blended in equal volumes would give the neutral gray tint is not confirmed by our experiments except in the case of the ammoniacal fluids.

---

[5] See footnote 4, p. 200.

THE SCOPE OF THE STANDARD COLORED FLUIDS.

It is hoped that the testimony thus far produced shows beyond cavil the fact that practically every tint of color as manifested in fluids can be duplicated by the proper blending of a few standard colored fluids.

We have shown that if the analyst adds to his stock of reagents and volumetric solutions five other assayed fluids, namely, acidulated half-normal cobalt chloride, acidulated half-normal ferric chloride, acidulated half-normal copper sulphate or copper chloride, ammoniacal tenth-normal roseo-cobaltic chloride, and ammoniacal tenth-normal ammonium dichromate, he will have all the essential ingredients from which, by blending or diluting, he can prepare any desired hue.

Of the eight standard fluids recommended as blending ingredients, the "Co-Fe-Cu" fluids are provided for in the list just given. The standard ammoniacal fiftieth-normal chromate and cobalt fluids are prepared from the tenth-normal solutions by proper dilution, while the ammoniacal fiftieth-normal copper solution can be prepared directly from the standard half-normal copper solution. The hundredth-normal dichromate and the thousandth-normal permanganate are prepared by diluting the regular U. S. P. standard volumetric solutions that every well-equipped laboratory keeps on hand.

As to the keeping qualities of the standard colored fluids and their blends, we showed in the *Druggists' Circular* article that the "Co-Fe-Cu" solutions and blends were practically permanent. Lovibond readings of samples a year old were approximately the same as readings made when they were freshly prepared. Samples of the blends that are now three years old show some color difference, but it seems reasonable to consider as stable a reagent that remains unchanged for more than a year.

As to the ammoniacal "Co-Cro-Cu" solutions, the standard cobalt and chromate fluids are practically permanent for six months or even a year if they are kept in well-stoppered bottles. The ammoniacal copper solution shows precipitation within a few weeks after preparation, its stability depending on the amount of free ammonia in it and also on how tightly closed the bottle is kept. As it is a very simple operation to prepare it freshly from the half-normal standard acidulated copper solution, this should be done when it is needed for accurate work.

The permanganate and dichromate solutions, while stable when kept separately, are not permanent when mixed. Blends of these two are not dependable for more than an hour or so after mixing, and consequently should be freshly prepared when needed.

THE SIGNIFICANCE OF THE STANDARD COLORED FLUIDS.

Having shown that practically every hue can be produced by proper blending of the eight standard colored fluids—the "Co-Fe-Cu," the "Co-Cro-Cu" and the permanganate-dichromate solutions—it is pertinent to ask, "Of what importance are these fluids and their blends?"

In the first place, we believe that further study of these fluids will throw much light on the problem of the relationship between color and the molecular structure. We might point out the curious fact that, barring the platinum group, the only metals that provide colored ions are the six whose atomic weight are in sequence.

Chromium Atomic weight	Manganese Atomic weight	Iron Atomic weight	Nickel Atomic weight	Cobalt Atomic weight	Copper Atomic weight
52	54.93	55.84	58.68	58.97	63.57

What relationship exists between the color and the other physical data concerning these fluids further experimentation alone will show. The immediate importance of these standard colored fluids and their blends is demonstrated by the question of practical color standardization which started the investigation, of which this paper is the fifth contribution.

There is great need for a simple and practical standardization of colors that will have a scientific rather than empiric basis. In music we have practical standards of sound pitch in the air column and vibrations of the tuning-fork, the latter being a practical appliance which is understood even by the unscientific mind. In color the only definite standard is the exceedingly difficult measurement of the length and the speed of the vibrations of light waves, and up to the present time not only have all efforts to gauge colors been empiric, but in many cases the color standards, such as lithographed plates and dyed fabrics, have easily faded on exposure to light.

The color standards described in this article have advantages over any other hitherto suggested in the following way:

1. They are scientifically exact, since based on the molecular weights of their constituent salts.

2. They are simple and easily duplicated, since they are prepared and standardized by methods that can be carried out without difficulty by any chemist.

3. Of the eight standard fluids, the five that should be assayed are more stable than any other proposed color standard except glass; the other three can be prepared in a few minutes from stable solutions, two of which are always a part of the stock in every well-equipped chemical laboratory.

4. While these colored fluids may not be as stable as colored glass, they possess marked advantages over that material, in that they are easily prepared and quickly duplicated.

5. The device of preparing blends by admixture of the three primary colored fluids in any proportion desired by the operator permits the production of infinitesimal differences in shades, while the fact that they are fluids miscible with water allows any intensity of color that may be desired.

6. While the work so far is concerned only with colored fluids, and while it is not a simple matter to match an opaque reflected color with a transparent one, our preliminary experiments in that line have shown us that the ultimate solution of that phase of the problem is merely a matter of further work.

PRACTICAL APPLICATION OF THE COLORED FLUIDS.

Extending the question "Of what importance are these colored fluids and their blends?" to the field of every-day work, the best answer we can give is that during the past winter we have studied several colorimetric tests and have found matches for their tints in blends of our standard fluids. The tests which we have so far studied in the above connection are as follows:

1. Nitrogen as ammonia with Nessler's reagent.
2. Nitrogen as nitrate with phenol-sulphonic acid.
3. Nitrogen as nitrite with naphthylamine and sulphanilic acid.
4. Vanillin with bromine water and ferrous sulphate.
5. Vanillin with phosphotungstic-phosphomolybdic acid reagent.
6. Uric acid with phosphomolybdic acid.
7. Phosphorus pentoxide with ammonium molybdate.

8. Salicylic acid with ferric chloride solution.

The first five in this list were given some attention in the *Druggists' Circular* article already referred to, but our recent work on them has been of a much more exhaustive nature. The rest of the tests mentioned have been corroborations of various authorities in so far as merely chemical tests are concerned; but the process of matching them against our standard fluid blends has been work in a virgin field. The practical results of all the nine tests will be taken up in detail in another paper.

COLUMBIA UNIVERSITY COLLEGE OF PHARMACY,
June, 1915.

Life-testing Equipment for Tungsten Lamps. ANON. (*Electrical World*, vol. 66, No. 1.)—Very few lines of work require voltage to be held within the narrow limits of one-tenth of one per cent., but in the accurate testing of incandescent lamps potential precision is regarded as a prime essential. Therefore, in planning the new life-testing equipment for the National Lamp Works of the General Electric Company at Mela Park, Cleveland, precise voltage regulation and economical construction were the guiding factors in an installation embodying many unique and original ideas.

As is well known, the tungsten lamp is sensitive to variations of voltage, and to obtain a good and uniform life it is necessary, even in a commercial way, to keep the voltage well under control. The fundamental part of lamp-life testing is the preservation of accurately uniform voltage at the testing racks. The pains taken to secure this are described in detail.

The Pennsylvania Railroad Test Department. C. D. YOUNG. (*Railway Age Gazette*, vol. 89, No. 7.)—The indifference of American manufacturers to the benefits of maintaining adequate laboratories of inspection and research, as compared with the activity in that field of foreign industrial organizations, has been a matter of frequent comment. A notable exception to this rule will be found in the description of the splendid development of the Pennsylvania Railroad Test Department in a paper read at the annual meeting of the American Society for Testing Materials, held at Atlantic City, June 22 to 26, 1915. From its humble beginnings in 1874 the work of the department has increased at an average rate of over 100 per cent. in each year, till the number of routine physical tests conducted reached, in 1912, a total of 120,000, the carrying out of which required the services of 300 employees. Although the cost of operating this department for one year, $534,000, seems enormous, it amounts to only 0.6 per cent. of the material inspected and tested.

Plating by Impact. ANON. (*Scientific American Supplement,* vol. lxxxix, No. 2060.)—The Schoop process of plating by means of a metal spray is now well known and in commercial use. A process of the same type has been in course of development by C. F. Jenkins, of Washington, D. C. This process can best be understood if it is remembered that when an electric lamp bulb gives way a discoloration of the inside of the bulb occurs, and also that when a fuse plug "blows" the mica cover is discolored. This color is black when the fuse is of lead, but it is a reddish color when a piece of copper wire is used. This would seem to indicate some kind of deposit resulting from the blowing of the fuse, that it is not completely volatilized. Under a magnification of 300 diameters or more, minute particles of the copper wire are discovered adhering to the cover of the fuse plug, and, when a common visiting card is used for a cover instead of the mica, a decided deposit is attained. Repeated charges of such a fuse result in a complete coating of the card. When this surface is burnished with some smooth, hard object, a shiny polished metal surface results. A fuse used in this manner is, in effect, a gun which throws out a shower of miniature shot so small as to be invisible to the naked eye, and this would operate successfully for covering almost any surface but for the annoyance of the frequent replacements with short pieces of copper wire. This led naturally to the development of a special "gun" into the barrel of which a copper wire is continuously fed. A pair of small rollers actuated by a motor pulls the wire off the supply spool and projects it across the barrel until the end touches the opposite surface. The inner lining of the barrel and the propelling rollers form a short circuit. The wire is immediately melted, and the heat causes it to be thrown out of the barrel against any object held in position for that purpose. When a plurality of wires or a flat ribbon is used in order to cover a larger area in a given time, it is found desirable to add a propelling force, and this is done by introducing into the barrel behind the wire a small charge of explosive gas. The melting of the wire explodes the charge which projects the miniature metallic particles that are momentarily suspended in the gas against the object to be coated. It has been found that objects in great variety can be coated in this manner, and that any electrically conductive material can be used for the purpose.

Agate and Onyx. Press Bulletin. (*U. S. Geological Survey,* June–July, 1915, No. 223.)—The distinction between agate and onyx is not apparent to every one, as indicated by the samples of the two minerals received by the United States Geological Survey with requests for information. Onyx marble or Mexican onyx is composed of calcium carbonate or banded limestone. True agate is a variety of silica. Onyx marble is much softer than agate and is rarely used for gems, but when onyx is obtained in pieces of sufficient size it is cut and polished for small objects like inkstands and paper weights, as well as for table tops and soda fountains.

A FLICKER PHOTOMETER ATTACHMENT FOR THE LUMMER-BRODHUN CONTRAST PHOTOMETER.*

BY

E. F. KINGSBURY,

Physical Laboratory, The United Gas Improvement Company, Philadelphia.
Member of the Institute.

Equality-of-brightness photometers and flicker photometers have heretofore been built entirely separately from one another. In the literature of the measurement of light the design and use of the one has been a distinct problem from the design and use of the other, though the results the former gives are often used as a criterion for the practicability of the latter. Consequently, in constructing a flicker photometer, it has been built from the beginning just for the one purpose, notwithstanding the fact that about half of a flicker photometer is identical with an equality-of-brightness photometer in its essential requirements. It should be possible, by interchanging the two dissimilar parts on the part common to both, to make either one easily converted into the other type of photometer. The result should be a photometer that is simple, compact, and capable of measuring either lights of one color or lights of widely different colors with the best precision of the equality-of-brightness method in the one case and of the flicker method in the other.

At the same time it is felt that such an instrument should embody the latest approved features that are coming to be recognized as desirable in a flicker photometer.

It is the purpose of this paper to describe such an instrument which the author has devised in the shape of a flicker attachment to replace the telescope of the ordinary Lummer-Brodhun contrast photometer when it is desired to measure differently colored lights. The high precision and the wide distribution of this type of equality-of-brightness photometer justify its selection for this purpose, although there are other good instruments to which this idea could be even more easily applied with a slight modification of details.

The various details concerning this attachment will be better appreciated if, before describing it in detail, we briefly review the essential requirements of a flicker photometer.

---

* Communicated by the Author.

Wilde[1] says the desiderata for an ideal photometer are:

1. It must be sensitive and certain on lights of different color.
2. Rays must fall upon the illuminated surface perpendicularly to reduce angle errors.
3. Illuminated surfaces should be directly over pointer on the bar.
4. When balance is nearly obtained, it should be easy to perceive which way the head must be moved to improve the balance, without the necessity of rocking it to and fro.
5. If complete reversibility is required, both illuminated surfaces should be identical and must be the same distance from the eye.
6. In a flicker photometer, in order to secure sensitiveness, the transition from one surface to the other must be sudden and there must be no dark line crossing the field of view, such as an unilluminated edge of a card.

These requirements are subject to considerable modification and addition. They are given, however, as illustrating a certain viewpoint in the construction and use of flicker photometers and to emphasize the employment of a proper photometric procedure.

The use of the substitution method of photometry is strongly recommended with the direct measurement of distances wherever necessary.

This makes the second, third, and fifth requirements unnecessary.

The fourth requirement is misleading, because one cannot obtain a satisfactory balance with the flicker photometer by merely looking at it in one position. The proper method of obtaining a setting is rapidly to vary the light intensity back and forth over the no-flicker peak, at the same time gradually narrowing the range until the point of minimum or no-flicker is found. The essential requirements only will be outlined below. They will not be discussed in detail, as they have been fully covered elsewhere.[2]

The sensitiveness or precision requirements of a flicker photometer depend fundamentally upon one thing—the focusing of the observer's maximum attention upon the elimination of intensity flicker. The attention is secured in a rather negative way by eliminating all external factors that can divert it.

---

[1] *London Illuminating Engineer,* p. 825, i, 1908.

[2] *Phil. Mag.,* July–December, 1912, pp. 149, 352, 744, 845.

First, undue tiring of the eyes should be guarded against. This is secured mainly by making the field surrounding the flickering field light instead of leaving it dark. The intensity of this illumination should be equal to, or less than, the intensity of the comparison field. If brighter, it attracts the attention. The intensity and color of this field do not seem to influence the accuracy, at least within wide limits. This field should be illuminated uniformly and should be free from mechanical defects.

Secondly, there should be no mechanical flicker in the comparison field itself. This is secured by keeping the optical system clean and making its focus in space and not on a surface. The focus of the eye-piece lens, of course, should be on the plane of the opening through the external field just referred to.

Thirdly, in securing a balance, the color flicker (as distinguished from the intensity flicker) should be reduced to a minimum by a proper regulation of the speed of alternation of the colors.

The requirements that make for agreement with the equality-of-brightness method are in each method:

First, a restricted field; and

Secondly, a high illumination on this field.

Dr. H. E. Ives has found that on a field size of about 2° and at an illumination of about 25-metre candles the flicker method and the equality-of-brightness method agree in their results, provided the same conditions are complied with in each case. A restricted field and a high illumination are somewhat interchangeable, but the candle-power of many standard lamps and other light sources places a limit on the illumination, so that the field is restricted to make it equivalent to a higher illumination.

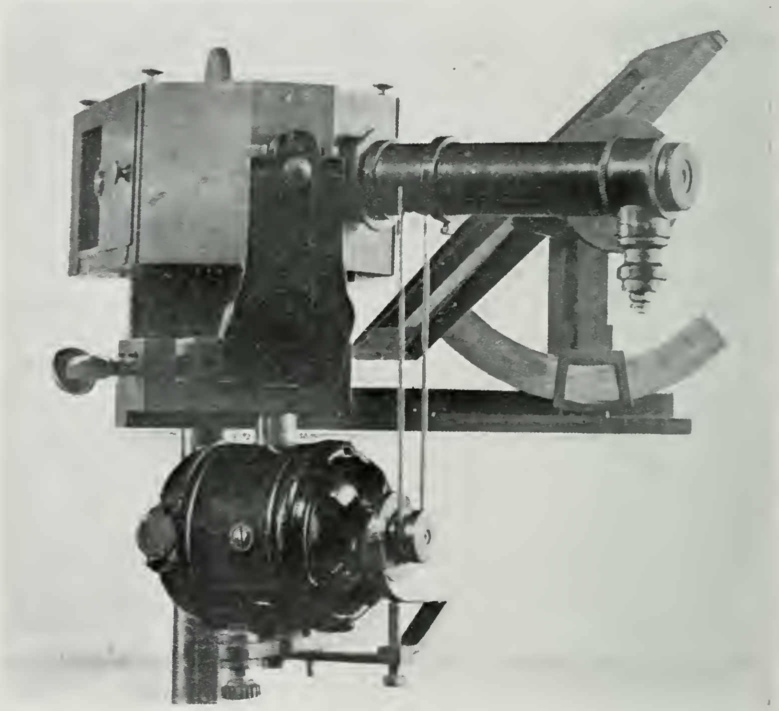
The requirements having to do with procedure have been mentioned; namely, that the substitution method be used with the direct measurement of distances. Where it cannot be done, care must be taken to reverse the comparison head and also the lamps under test, unless complete reversibility of each has been shown to yield identical results.

The method of securing a balance with the flicker photometer mentioned above should be emphasized here. The relative intensities of the two lights under test should be capable of being easily and quickly varied over a considerable range. One method of doing this is shown below.

In making a setting the light should be varied back and forth over the region of minimum or no-flicker, and the limits gradually narrowed down to a balance. It is impossible to obtain good precision or accuracy by leaving the setting at any one point and trying to decide whether it is the correct point. There is no criterion for the judgment unless the intensity is changed.

The last general requirement is one of convenience. The parts should be easily accessible for cleaning, repairing, and demonstration.

FIG. 1.



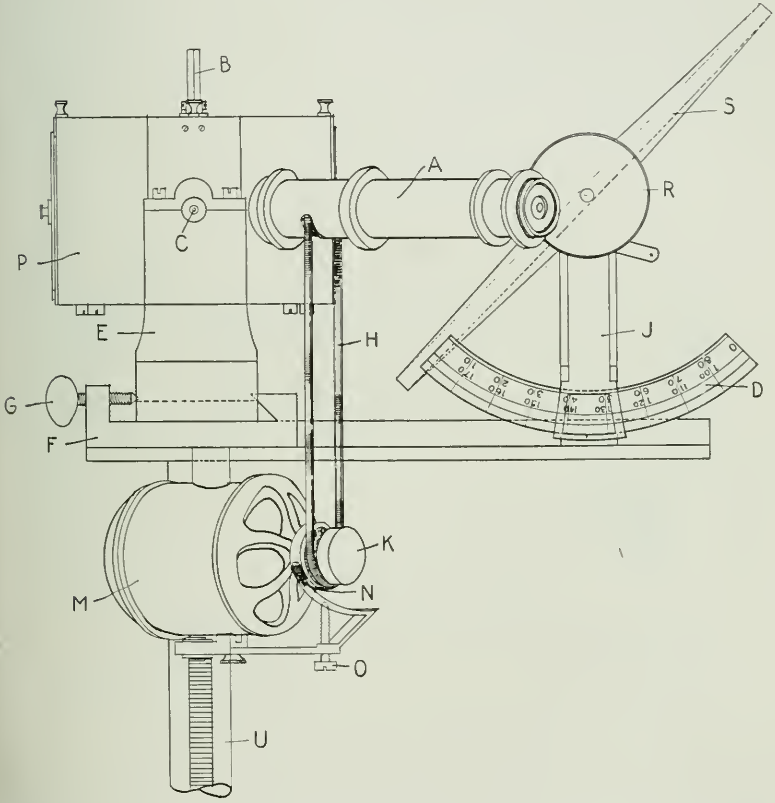
The Lummer-Brodhun with flicker attachment, motor, and neutral tint-absorbing screen.

The attachment, with the motor and a neutral tint-absorbing screen, is shown in position on a Lummer-Brodhun head in Fig. 1.

Fig. 2 shows an elevation of the same.

The attachment (*A*) screws into the head in place of the regular telescope. The only other change necessary in the Lummer-Brodhun is the removal of the contrast glasses, which the heads are built to permit readily. A belt (*H*) runs from the rotator within the tube to the motor (*M*), which is fastened to a clamp (*F*) that fastens to the horizontal casting beneath the box. The belt (*H*) is made of spirally-wound steel wire. It acts as a spring to take up any slack, and allows of the belt being easily slipped off the motor pulley. The part shown to the right is an addition, proposed by Dr. H. E. Ives, to facilitate reading, in the shape of a neutral tint-absorbing screen formed of parallel wires

FIG. 2.

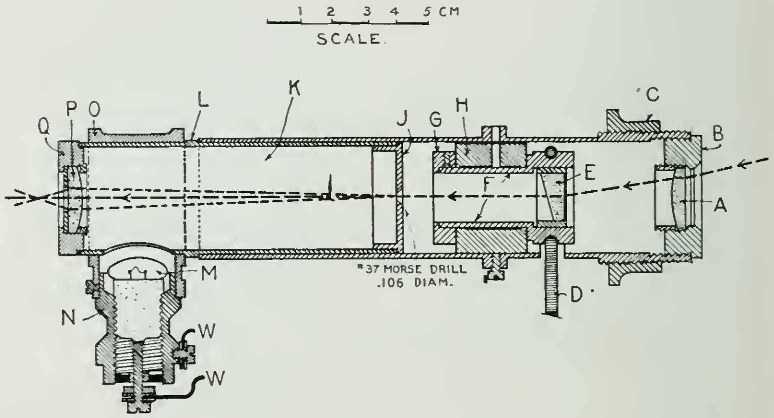


Elevation of Lummer-Brodhun with flicker attachment, motor, and neutral tint-absorbing screen, showing the method of clamping it to the head.

A. Flicker attachment.
B. Comparison disk.
C. Axis of head.
D. Scale.
E. Casting supporting head.
F. Clamp.
G. Clamp screws.
H. Belt.
J. Index.
K. Pulley.
M. Motor.
N. Friction brake.
O. Brake screw.
P. Lummer-Brodhun box.
R. Screen knob.
U. Support.

in the frame (*S*). The frame is turned by knob (*R*) and the transmission read on the scale (*D*). This screen permits the light intensity to be easily and quickly varied over a considerable range, the desirability of which was mentioned above. In most cases it is more convenient to use such a screen than to move the light or the photometer head, though originally the attachment was intended to be used as the Lummer-Brodhun contrast head would otherwise be. Dr. Hugo Kruss[3] has a screen attached to his contrast photometer that would likewise undoubtedly work nicely with the flicker attachment, if the micrometer thread is not too fine. *O* on the motor is a friction brake designed to allow the speed to be changed quickly and easily over a wide range.

FIG. 3.



Elevation of flicker attachment.

A. Front lens.
B. Collar for lens.
C. Collar to hold telescope rigid in head.
D. Belt.
E. Rotating prism.
F. Rotator bearing.
H. Stationary bearing for rotator.
J. Front of eye-piece.
K. Eye-piece.
L. Collar on eye-piece.
N. Lamp socket.
O. Rotating collar for lamp.
P. Eye-lens.
Q. Collar for lens.
W. Wires to lamp.

The attachment is shown internally in elevation in Fig. 3.

The right end of the tube screws into the Lummer-Brodhun, and when the tube is in position, with the belt (*D*) downward to the motor, the collar (*C*) is screwed tightly against the box. This brings the attachment central and square on the head and at the same time renders it rigid. *A* is a lens setting in a collar (*B*) that magnifies the Lummer-Brodhun field properly. *E* is a prism that sets in a cylindrical piece (G), the whole being rotated in bearing (H) by the belt (D). The bearing (H) is held in position by a screw beneath the tube. Upon loosening this screw the bearing with the rotating piece containing the prism can be slipped out of the tube either way if the belt (D) is first unhooked and pulled out. K is the eye-piece, which consists of a brass tube covered at the far end with a disk (J), in the centre of which is the hole making the 2° field mentioned above. The eye lens is at P, set in a collar (Q). The entire interior of this eye-piece (K) is painted white, and at M is placed a small 2-volt pocket torch-light which, when lighted, sends its rays up in the eye-piece. This, in turn, being a matt white, acts as an integrating sphere and diffuses the light so well that in looking into the eye-piece through the lens one sees surrounding the 2° opening a uniformly-illuminated surface. To allow the adjustment of the brightness of this surface to suit the observer, the socket (N) into which the light sets is fastened to a collar (O) which turns on the eye-piece (K) and moves the lamp over the solid part of the eye-piece, the whole arrangement acting as a shutter. It allows of the illumination being changed from too bright to absolute darkness and at the same time always keeping it uniform. A spring in the collar (O) pressing on the eye-piece insures the collar always turning smoothly. This collar can be slipped off the head of the eye-piece. The lamp socket (N) can be slipped out of the collar on loosening a set screw to allow the replacement of the lamp. L is a small collar fastened to the eye-piece that limits the distance which it can be slipped into the attachment tube, and at the same time the turning collar (O) bears against it on the opposite side. When it is desired to remove the eye-piece (K) it is simply pulled out of the other tube, bringing J with it. The white surface is thus never exposed to careless handling. Fixed resistances, not shown, go in series with the lamp and motor. They both are intended to operate on 110-volt line to the head.

---

[3] *Jnl. f. Gasbel.*, p. 457, 1914.

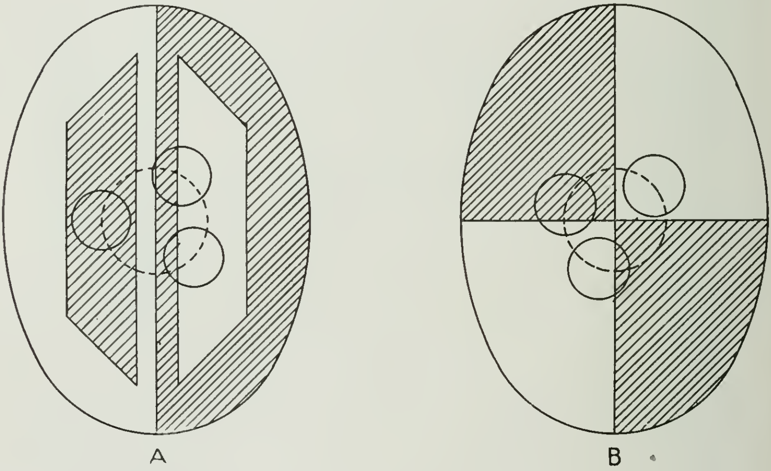
The method of cutting the Lummer-Brodhun field is shown in Fig. 4 *A*. The dotted line shows how it goes from trapezoid to trapezoid, the circles representing three different positions of the rotating prism. *B* shows the four-part field used in the laboratory flicker photometer recently built in this laboratory.[4] This four-part cube can be easily put in a Lummer-Brodhun box to replace the present one, if this type of field is preferred with the attachment. A question to be answered by the construction of this instrument was whether the irregular type of alternation given by the Lummer-Brodhun field would result in less precision or accuracy than the four-part field. No difference was found on trial, the irregular alternation of fields apparently calling merely for a lower speed.

---

[4] *Phys. Review*, iv, p. 222, 1914.

The real value of such an instrument as described is best shown in actually measuring large color differences. A deep red monochromatic signal glass whose transmission was accurately known was measured against a 1.15 w.p.c. tungsten light on the other side; likewise a green signal glass and a 4 w.p.c. carbon lamp against the tungsten. In each case it has been found equal in precision and accuracy to the large laboratory instrument just referred to. The focus of the optical system of the attachment is in space and not on a surface, and, although the attachment was tested on a photometer head whose mirrors were badly corroded and needed replacing, no trouble was experienced from mechanical flicker.

FIG. 4.



To show how the Lummer-Brodhun field (*A*) is cut by the attachment; also a four-part field (*B*).

It should be made plain that this attachment does not obviate the necessity of a proper selection of observers if the result is to represent that of an average eye. At least five observers should be used in this case, as has been carefully explained in a paper recently published concerning this point, to which the reader is referred.[5] This is required of all flicker photometers.

In addition to the above point, care should be taken to remove the contrast glasses of the Lummer-Brodhun in using the attachment. If this is not done there will always be an outstanding intensity flicker. This point has been mentioned previously, but it is repeated here for emphasis.

The thanks of the author are due to Dr. H. E. Ives for many helpful suggestions, and especially to Mr. C. B. Smith, the laboratory's mechanic, who has taken a deep interest in perfecting many mechanical details.

PHYSICAL LABORATORY,
The United Gas Improvement Company,
May, 1915.

Electroplating with Cobalt. C. H. BUCHANAN and THOMAS HADDOW. (*The Metal Industry,* vol. 13, No. 6.)—This paper, prepared for the New York Branch of the Electroplaters' Society, contains data and results of experiments covering a long period, made by the writer, C. H. Buchanan, and a report of experiments of recent data in collaboration with Thomas Haddow. Early experience showed that a chloride-cobalt solution deposited more rapidly than did a nickel solution. Subsequent work done with cobalt proved so satisfactory that if the cobalt metal could have been obtained in sufficient quantities from commercial sources, even at a cost higher than paid for nickel, it would have been adopted for general work. The results of recent tests are summarized as follows: Cobalt plating has a beautiful bluish-white color. The deposit does not tarnish as readily as nickel; it is homogeneous, with a fine, close grain; it is smooth and not brittle, and will easily withstand bending tests. The time required in order to secure a satisfactory deposit is much less with cobalt than with nickel, and the current density with cobalt may be greater. Metallic cobalt costs more than nickel, but the cost of the salts is of small importance in a comparison of the two as to economy in results. Because of the greater conductivity of cobalt as compared with nickel, a current of higher density may be used in combination with a solution of less concentration. The time required in the solution is, with cobalt, one-third that required for nickel, and there is a similar saving of time in the buffing-room. The substitution of cobalt for nickel would thus greatly increase the speed of production in any established plant.

---

[5] *Trans. Ill. Eng. Soc.*, 1915; *Phys. Review,* v, p. 230, March, 1915.

Expansion of Briquetting Industry. (*Commerce Reports,* 1915, No. 150.)—Although the number of briquetting plants in the United States was reduced from seventeen in 1913 to sixteen in 1914, there was a substantial increase in output of briquetting fuel. In this collateral branch of the coal-mining industry, which is still in the early stages of development, the smaller plants are going out of existence and the new establishments are of greater capacity. The briquettes favored in the Eastern States are egg-shaped and about the size of anthracite nut. In the central and Pacific coast States the popular type of briquetted fuel appears to be the larger size, about that of egg coal, for which the raw materials available seem best adapted. The material available for manufacturing briquettes in the Eastern States is culm from Pennsylvania anthracite mines and southwestern Virginia semi-anthracite mines and non-coking bituminous slack. Slack from the non-coking bituminous and sub-bituminous coal of the middle western and Rocky Mountain States is another cheap and abundant raw material for briquettes. The vast and almost untouched areas of lignite in North Dakota and Texas contain enormous supplies of fuel that European practice has taught is well adapted to briquetting, and is much more usable in that form than in a raw state.

Talc and Soapstone. (*U. S. Geological Survey.*)—The United States produces more talc and soapstone than all the rest of the world combined. Moreover, according to J. S. Diller, of the United States Geological Survey, our production has nearly doubled in the last decade, increasing from 91,185 short tons, valued at $940,731, in 1904 to 172,296 short tons, valued at $1,865,087, in 1914. Of talc alone the United States produced 151,088 tons, and of soapstone 21,208 tons.

Talc is a simple mineral of which soapstone is an impure massive form. Few people are aware how much we owe to talc and soapstone. It is one of the softest of minerals. It is so smooth and slippery that it has become a great panacea for friction in many branches of human industry.

There are nine States producing this useful mineral. New York continues to be the leading producer, yielding more than 57 per cent. of the total production of talc in the United States and far outranking all other States excepting Vermont, which has in recent years so greatly increased its production that in 1914 its output was about three-fourths that of New York. Of soapstone, Virginia holds the greatest supply, and backed up by Vermont it meets the great demand for washtubs, sinks, and fireless cookers.

Talc is used in making talcum toilet powder, the tailor uses it to chalk fabrics for new suits, and talc "slate pencils" and crayons have enabled many scholars to solve knotty problems. Talc bleaches our cotton cloth, and in paints we see it everywhere, but its chief use is as a filler in paper of many kinds, from roofing to news paper.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

THE USE OF SODIUM SALTS IN THE PURIFICATION OF CLAYS AND IN THE CASTING PROCESS.

By A. V. Bleininger,
Ceramic Chemist, Bureau of Standards.

[ABSTRACT.]

THE present work deals with a technical investigation of the effect of small quantities of sodium carbonate and sodium silicate in the separation of the impurities from kaolins and in reducing the water content in raw porcelain mixtures composed of kaolin, ball clay, feldspar, and quartz, ground together in water to form a suspension which is used to cast clay wares.

It has been shown that kaolinitic clays may be decidedly improved by carrying on the washing process with water containing a definite, small amount of caustic soda or a mixture of caustic soda and sodium silicate. This makes possible more complete sedimentation of the granular impurities which it is desired to remove. This treatment improves the color of most clays, enriches their content in clay substance, decreases the drying shrinkage, but tends to increase the burning shrinkage. Clays containing iron in the form of finely-divided ferric oxide cannot be treated successfully by this process.

The electrical osmosis process, invented by Count Schwerin, consisting in collecting the negatively-charged clay and quartz particles on the positive electrode under the influence of a direct current, plays no important part in the purification of clays. Its function seems to be purely mechanical. It thus replaces the filter press, and if the latter is of the modern improved type any advantage resulting from continuous and automatic operation will be more or less neutralized. The higher the voltage of the current employed the denser will be the deposit of clay and the lower in water. The preliminary sedimentation process using caustic soda or other electrolytes seems to be the real feature of the osmose process. The electrical method of separation cannot remove finely-

---

* Communicated by the Bureau.

divided ferric oxide. It also deposits with the clay any finely-divided quartz which may be in suspension.

The efflux viscosimeter appears to be satisfactory for the technical study of casting slips.

Sodium silicate is a more effective reagent, so far as the reduction of viscosity is concerned, than sodium carbonate.

North Carolina kaolin in suspension is not influenced by the reagents in question in a marked manner, due to its comparative coarseness.

Georgia kaolin has a far greater initial viscosity than the North Carolina kaolin, and appears to be very sensitive to additions of sodium carbonate. It shows a well-defined minimum of short range, which rapidly turns toward a maximum. Its range at minimum viscosity is greater when sodium silicate is used.

Tennessee ball clay No. 3 gives no indication of a decided minimum viscosity point.

Florida kaolin responds decidedly to the addition of sodium carbonate, but a well-defined minimum is not reached, probably due to the comparatively large amount of pseudo emulsoid or lyophile substance produced. With sodium silicate the viscosity decrease is equally great, with no tendency to approach another maximum value.

A large volume of air seems to be absorbed in clay slips, the removal of which increases the viscosity. Thorough and vigorous stirring of the slip, therefore, seems essential, and exhaustion by vacuum might be beneficial. The effect of the entrapped air was more prominent with lower alkali concentrations and with the Georgia and Florida kaolins.

A body containing North Carolina kaolin, Florida kaolin, and Tennessee ball clay proved to respond well to the addition of sodium carbonate, but showed a turn towards greater viscosity (recoagulation) for additions greater than 0.06 per cent.

A commercial slip, fairly high in English ball clay, showed a rapid drop in viscosity, but required a much higher per cent. of the reagent mixture than the single clay bodies. The viscosity seemed to remain constant at the minimum value. It is possible that this condition is due to the presence of organic colloids which exercise a protective influence.

Interaction occurs between different clays with respect to viscosity changes, independent of the alkali additions, and these are not necessarily proportional to the ratios of the admixed clays or regular in character. It is important, therefore, to know just what this interaction is, since it is quite possible that some clays may have a detrimental effect upon the others in making up the casting body. The ball clay content in a casting slip should be reduced to the minimum.

Absorption of the alkaline reagents plays an important rôle in casting slips. Sodium hydroxide is absorbed to a far greater extent than the carbonate, and probably combines chemically with the clay.

The tensile strength of cast bodies containing alkali additions may be greater than that of the same materials cast without these reagents. Single clay body slips, used in the state of maximum deflocculation, do not seem to be weaker than when the suspensions are carried only to a point to the left of minimum viscosity.

Casting bodies with low concentrations of alkali are more apt to change their viscosity with time than those containing larger additions.

AN INVESTIGATION OF FUSIBLE TIN BOILER PLUGS.

By G. K. Burgess, Physicist, and P. D. Merica, Assistant Physicist.

THE failure and deterioration of fusible tin boiler plugs in service have been investigated. In some cases such plugs have failed to melt and so give warning of dangerous boiler conditions, and investigation has shown that the tin filling in these cases had become oxidized to tin oxide (SnO_2), which has a melting-point above 1600° C. (2900° F.).

About 1050 plugs, of which 100 were plugs which had been in service, were obtained through the courtesy of the Steamboat Inspection Service, Department of Commerce, and subjected to examination. This included inspection of design and construction, condition and purity of the tin filling, and, in the case of the used plugs, their classification according to the type of deterioration undergone by them in service.

One pronounced and dangerous type of deterioration is the oxidation of the tin along the grain boundaries by which is formed a network of oxide throughout the tin. The plugs showing deterioration of this type all came from the same manufacturer and contained zinc in amounts varying from 0.3 to 4.0 per cent. It is shown that this type of oxidation is due to the presence of this zinc. The latter metal is not soluble in the solid state in tin, and when a tin with small amounts of zinc is heated as in a boiler to about 180° C. (340° F.) this zinc coalesces as a network enveloping the tin crystals or grains. The boiler water, particularly if it contains alkali, will attack the zinc, eating its way into the alloy along the zinc network, and finally form the oxide network described.

Lead and zinc are found to be the principal impurities in tin plug fillings, and, since all " failed " plugs contained these or other impurities, the conclusion is reached that if these impurities are eliminated by strict specifications and inspection, which will allow only admittedly superior qualities of tin, such as Banca and some others, the danger of failures of these plugs will no longer exist.

In order to test quickly the purity of a tin sample a determination of its freezing-point may be made. This can be done conveniently with two or three grammes of the sample, and requires only inexpensive apparatus, including a high-resistance millivoltmeter and a copper-constantan thermocouple.

ELECTROLYSIS MITIGATION.*

THE paper gives a general discussion of the subject of electrolysis, comprising a comparison of electrolysis conditions in America with those in other countries, a discussion of electrolytic corrosion proper as distinguished from self-corrosion, and touches briefly on electrolysis effects in concrete and steel buildings. There is also a brief discussion of the effects of stray currents other than corrosion, such, for example, as the production of fires or explosions.

Methods of electrolysis mitigation are discussed at length. All of the various methods of mitigation that have been proposed or tried are discussed under two main heads: First, those methods applicable to underground pipe and cable systems; and, second, those applicable to the railway negative return. Those methods applicable to underground pipe systems comprise the following: (1) Surface insulation of the pipes; (2) chemical protection,— that is, rendering the pipe surface passive by surrounding it with earth filled with lime or other chemical that will prevent corrosion;

---

* Abstract of Technology Paper.

(3) cement coatings; (4) cathodic protection,—that is, maintaining the pipe or cable always negative to earth by means of a motor generator set or battery or other sources of electromotive force; (5) favorable location of pipe with respect to tracks; (6) the use of non-corrodible conducting coatings; (7) electric screens; (8) the use of insulating joints in pipes; and (9) pipe drainage.

The discussion leads to the conclusion that of the various methods under this class that have been tried none are suitable for general use as primary means of preventing electrolysis trouble. The methods of chemical protection, cement coatings, cathodic protection, and conducting coatings should be regarded as substantially worthless in their present state of development. Surface insulation of pipes by means of paints or dips is not much more reliable, but insulation by putting pipes in troughs or conduits filled with pitch may be used in special cases where the expense would be justified. The practice of placing all pipes as far as possible from railway tracks affords a certain measure of protection, of which advantage should always be taken wherever practicable in laying new lines or relaying old ones. The use of electric screens is often a valuable expedient in taking care of acute local cases of trouble in existing mains.

These methods, with the exception of that relating to the proper location of pipes in new work, are suitable only to special conditions, however, and are not usually to be considered as important factors in any general plan for electrolysis mitigation.

Pipe drainage is sometimes useful, but should be used with proper restriction and with due precautions against setting up any dangerous conditions either in the system drained or in neighboring systems. In general, in city networks where there are a number of independent underground systems to be protected pipe drainage should be used as little as possible, the chief reliance being placed on mitigative measures applied to the railway negative return. The drainage of lead cable systems will, however, usually be desirable, and these should always be drained by means of suitable insulated feeder systems so arranged as to drain the least practicable current from the cables in order that neighboring structures may not be subjected to unnecessary danger thereby.

The most valuable mitigative measure that can be applied to the pipe system consists in the proper use of insulating joints, and the extensive use of such joints should be encouraged in new work and in making repairs. Precautions are necessary in their use, however, and these are set forth in the discussion.

Taking up the methods applicable to the railway system, there is a very brief reference to the alternating-current system, double-trolley system, the use of negative trolley, and the periodic reversal of trolley polarity. This is followed by a somewhat extended discussion of methods of reducing potential differences in the uninsulated portion of the negative return. These various means comprise: (1) Proper construction and maintenance of way; (2) grounding of tracks and negative bus; (3) use of uninsulated negative feeders; (4) use of insulated negative feeders without boosters; (5) use of insulated negative feeders with boosters; (6) three-wire systems; and (7) proper number and location of power-houses.

The discussion leads to the conclusion that the alternating-current system, the double-trolley system, the use of negative trolley, the periodic reversal of trolley polarity, and the use of uninsulated negative feeders in parallel with the rails, when considered solely as methods of electrolysis mitigation, are either impracticable or else open to the objection that the expense or operating difficulties attending their application are rendered unnecessary because of the fact that there are other adequate methods available for general application which are comparatively cheap to install and which introduce but slight complications into the operating system.

The importance of proper construction and maintenance of track return is emphasized, and the drainage of the roadbed where practicable is urged. Also where the track is laid on private right of way the rails and ties should be kept as far as possible out of direct contact with the earth by the use of good rock ballast.

It is also pointed out that the three-wire system, when viewed solely from the standpoint of electrolysis mitigation, possesses large possibilities. Attention is called to the fact, however, that up to the present time sufficient experience has not been had with this system to determine whether it is practical from the operating standpoint under average conditions of service. It is therefore urged that experiments with this system be made under conditions to which it is best adapted.

The most effective methods that have been thoroughly tried out in practice over long periods are the use of insulated negative feeders either with or without boosters, generally the latter. In most cases where the feeding distances are not too long an insulated feeder system without boosters will prove cheapest and at the same time more satisfactory because of its greater simplicity. It is possible, by the proper application of such systems, to reduce the potential gradients in the earth to such low values that in most cases little damage would result. In many cases, however, it may be better, where conditions are favorable, to combine one of these methods with either the insertion of a moderate number of insulating joints in the pipes or with the use of a very limited amount of pipe drainage, provided local conditions are favorable to the use of this method. The insulated feeder system would be applied to reduce the potential gradients throughout the system to very low values, and one or the other of the auxiliary systems used to eliminate largely any residual electrolysis that might still remain.

The last section of the paper is devoted to a discussion of regulations regarding electrolysis mitigation. The subject of what criteria should be used for determining the adequacy of electrolysis conditions is taken up at some length, and it is shown that potential measurements showing a total drop of potential in the railway negative return and also potential gradient measurements throughout the track network are very valuable. It is also shown that all-day average values of these potential readings give a better criterion of the actual danger from electrolysis than any short-time peak value. It is recommended that in fixing voltage limitations some plan analogous to the zone system should be adopted, the voltage limits prescribed for the various zones being determined largely by the degree of development of the underground utilities in the various zones. The voltage drops either in the tracks or in the pipes, and earth may be used as the basis for fixing limitations, but in general the latter is to be preferred. The question of what constitutes a safe limit for voltage drops in the track return is discussed at some length, and the conclusion is reached that for the overall potential drop in the railway tracks a limit of from two to four volts is reasonable and adequate, and the potential gradient should in general be restricted to 0.3 or 0.4 per thousand feet, these figures being all-day average values. Where short-time peak values are used, the figures would, of course, be considerably higher.

In order that ready determination of voltage drops may be made at any time, potential wires should be installed running from some central point to selected points on the railway or pipe networks. These points should include the points of approximately highest and lowest potential and preferably, also, some intermediate points. It is recommended that exemption from any regulations regarding track voltages should be made in special cases as described in the paper where local conditions make it improbable that any serious damage would result. The responsibilities of the owners of underground utilities regarding the mitigation of electrolysis troubles is discussed, and it is recommended that any regulations governing electrolysis mitigation should be made to apply not alone to the railway system, but should also define the responsibilities of the owners of underground utilities, since the latter can often contribute materially to the diminution of the trouble at a practically negligible cost.

THE VISCOSITY OF PORCELAIN BODIES HIGH IN FELDSPAR.

By A. V. Bleininger and C. S. Kinnison.

In this work the degree of softening of previously-fired porcelain bars subjected to a tensile stress of 14.5 pounds per square inch, at a series of temperatures between 1275° and 1380° C., was determined by measuring the elongation. The object of these tests was to obtain data for selecting compositions showing the greatest rigidity at the highest kiln temperatures for the purpose of selecting bodies causing least loss in manufacture due to deformed ware.

Higher contents of feldspar increase the viscosity of low clay compositions markedly. In a 45 per cent. kaolin-clay body, 35 and 40 per cent. of feldspar are most effective in decreasing the viscosity, but higher percentages again increase it. Still higher clay contents cause the softening effect of feldspar to diminish decidedly. Flint, in high feldspar bodies, does not seem to be an important factor in governing the viscosity. For high temperature porcelains high clay content is essential. High clay bodies having feldspar as the only other constituent show very great viscosity.

The function of viscosity is not a continuous one. After attaining a certain degree of softening, a well-defined rigid state ensues, which does not tend to approach further softening until a temperature of 1345° has been reached. Beyond this point the second stage of decided softening is entered upon. Although showing the same degree of viscosity at 1388°, bodies may be divided into several classes, according to the degree of softening observed between 1300° and 1345°. Within this temperature range greatest rigidity was shown by the following compositions:

Kaolin and clay, per cent.	Feldspar, per cent.	Flint, per cent.
40	30	30
45	35	20
45	50	5
50	30	20
50	50	..

STANDARDIZATION OF BOMB CALORIMETERS.*

THERE has just been issued by the Bureau a paper describing briefly the methods of calibrating and using bomb calorimeters, such as are used in determining the amount of heat available from a given weight of coal or coke or other combustible. The amount of heat which can be obtained depends largely upon the kind and quality of fuel. When purchased in large quantities a fuel is commonly tested to determine the amount of heat available per pound, and the price paid depends upon the results of these tests.

The instrument used for such tests is called the bomb calorimeter and consists essentially of a steel shell or "bomb" in which a small weighed sample of the fuel can be burned in pure oxygen gas. The bomb is immersed in a known amount of water before the sample is ignited, the heat produced warms the water, and by suitable measurements of the change of temperature the amount of heat can be calculated.

Provision is made by the Bureau of Standards for standardizing bomb calorimeters by means of standard samples of certain pure materials, viz., sugar, naphthalene, and benzoic acid. By burning known amounts of these substances in the bomb the observer determines the amount of heat required to raise the temperature of the bomb, together with the proper amount of water, one degree. This being determined, the amount of heat furnished by a given sample of coal burned in the same bomb with the same amount of water can be found.

---

* Circular No. 11.

Thus these standard samples, which are sent all over the United States, serve as standards of heat and make it possible to get the same results from tests made anywhere in the country, much as the use of the standards of length and of mass makes a yard or a pound the same in all parts of the country.

THE TESTING OF RUBBER GOODS.

THE Bureau is about to issue the third edition of a circular on the testing of rubber goods This publication, which has been very much enlarged, is fully illustrated and describes in detail the method of procedure in conducting physical and chemical tests of rubber. The testing machines and apparatus developed at the Bureau of Standards greatly facilitate the testing of rubber, and the object of this circular is to assist manufacturers and consumers in establishing standard specifications and standard methods of test. The subject matter proper is introduced by a brief outline of the processes through which rubber passes before reaching the factory, followed by a short description of the usual processes of manufacture, which include washing, drying, compounding, "making up" various articles, and vulcanizing. The physical tests most commonly employed are explained very thoroughly. These include tests for tensile strength, ultimate elongation, and elasticity. Conditions affecting the results of tests are discussed at some length, and experimental data are given to show the necessity of a standard procedure in testing.

A general discussion of the chemistry of rubber is followed by a brief explanation of the object of each of the analytical determinations that are commonly made. After this there are given in detail the methods in use at the Bureau for each of these determinations. They are not entirely original, but have been compiled from the various publications on rubber analysis, from the information gained through the routine testing of rubber goods for delivery on government contracts, and from coöperative research with various scientific organizations.

The tentative method of analysis and specification for 30 per cent. Hevea insulation compounds, adopted by the joint Rubber Insulation Committee, is next given.

A bibliography listing the more important books and journals devoted to rubber, and the Bureau's regulations regarding the testing of rubber goods conclude the circular.

NOTES FROM NELA RESEARCH LABORATORY.*

THE BRIGHTNESS-DIFFERENCE SENSIBILITY OF THE EYE UNDER VARIOUS BRIGHTNESS OF TEST-FIELDS AND SURROUNDINGS.†

By Percy W. Cobb.

THE problem consists in preparing a bright surface which shall fill the entire visual field and form the surroundings of a small field of independently variable brightness. The former is obtained by a device somewhat on the principle of the Ulbricht sphere, made in the form of a cube of one metre side, with its interior edges and corners cut off to form a polyhedron approximating a sphere. This is provided with an opening in one side, in which the observer's face is inserted, and the interior is illuminated through a diffusing glass in the oblique surface immediately above this. A small rectangular opening opposite the observer, 3.4 × 4.6 cm. and one metre away, forms the outline of the test-field, and is the plane of focus of an image formed by a projecting lens of a small illuminated milk-glass. A condensing lens just beyond makes the image appear to the observer to fill the opening. A second image formed by partial reflection and projected by the same lens is made to fall in the same place, and a device arranged so that it may be made to cover the right or the left half only of the test-field, as brightness added to that half, varied by means of an adjustable sector disk and measurable independently of the field-brightness itself.

Fourteen sets of conditions were used, namely: one in which field and surroundings were equal at 5.5 millilamberts (17.5 candles per square metre), seven (a to g) in which the field alone was varied from these conditions from 137 to 0, and six (u to z) in which the surroundings alone were varied from 38 to 0 millilamberts (436 to 0 and 121 to 0 candles per square metre). The results given in the table are each the mean results of 500 judgments of each of three observers. They are stated (1) as the absolute value of the addition to the half of the field necessary to be just visible, and (2) as the ratio that this bears to the field before addition.

---

* Communicated by the Laboratory.

† To appear in *Psychological Review.*

TABLE I.

Absolute and Relative Difference-threshold for Various Conditions.

	Brightness conditions Millilamberts *			Difference-threshold Millilamberts	
	Field	Surroundings	Ratio	Absolute	Fractional
a.	137.1	5.43	25.2	0.918	0.0067
b.	40.1	5.43	7.39	0.2373	0.0059
c.	11.09	5.43	2.04	0.0647	0.0058
o.	5.52	5.43	1.02	0.0289	0.0053
d.	2.803	5.43	0.52	0.0207	0.0074
e.	0.66	5.43	0.12	0.00952	0.0143
f.	0.1696	5.43	0.031	0.00672	0.0396
g.	0.000	5.43	0.000	0.00616	
u.	5.49	38.15	0.14	0.0672	0.0123
v.	5.52	14.44	0.38	0.0396	0.0072
o.	5.52	5.43	1.02	0.0289	0.0053
w.	5.52	2.715	2.03	0.0327	0.0059
x.	5.52	0.674	8.19	0.0371	0.0067
y.	5.52	0.1719	32.1	0.0421	0.0076
z.	5.52	0.000		0.0456	0.0082

---

* A lambert is defined as the brightness of a perfectly diffusing surface emitting one lumen per square centimetre, equal to a brightness of 0.3183 candle per square centimetre. A millilambert is 0.001 lambert.

The fourth column gives the ratio of brightness of field to brightness of surroundings. The sixth column the ratio of the threshold amount of brightness added to one-half of the field (column 5) to the original brightness of the field (column 2).

It is to be noted that with constant value of surroundings the absolute value of the difference rises as the field-brightness is increased (a to g). On the other hand, where the field is constant and its surroundings variable, the difference is minimal at the point where the latter equals the field-brightness, otherwise greater whether the surroundings exceed or fall below the field in brightness. These relations are more clear when we think of the threshold-difference as a fraction of the field-brightness (column 6) and compare it with the ratio of field-brightness to surroundings-brightness (column 4). In this case the former rises rapidly (in both series) as the latter decreases, and rises also as the latter increases, but only moderately.

ENERGY-DENSITY IN THE EYE-MEDIA.*

By M. Luckiesh.

In a previous paper on "Radiant Energy and the Eye" † the results of a large number of computations were presented to show the relative amounts of energy absorbed in various parts of the eye-media when beams of radiation from various illuminants pass through the eye as in ordinary vision. This work has been continued in a study of the mean energy-density in the various vertical sections of the eye under conditions of illumination from sources emitting (or reflecting) radiation of various spectral characters. Special attention is called to the widely different conditions in the eye; namely, when viewing objects subtending at the eye small and large solid angles, respectively. When the viewed object subtends a small angle, the mean energy-density throughout the eye remains approximately constant until the retina is approached. In other words, the concentrating action due to refraction is overcome by the progressive absorption of the eye-media. At the retina the mean energy-density becomes relatively very great. In the case of objects subtending a large solid angle the mean energy-density is much greater in the lens than at the retina. The question is important, in view of the fact that cataract and eye-fatigue are considered by many to be due to absorption of energy. As a practical application of the data obtained by computation, it is seen that a molten glass surface, such as a large pot of molten glass, appears as harmless as a small surface at the same distance (the retinal images being of the same brightness); however, the energy-density in the lens will be many times greater in the case of the surface subtending the larger solid angle at the eye. In fact, the ratio of the energy-densities in the lens (in the pupillary plane) will be approximately the same as the ratio of the solid angles subtended by the large and small surfaces, respectively.

---

* To appear in the *Electrical World.*

† *Electrical World,* October 25, 1913.

VISUAL PATTERN-DISCRIMINATION IN THE VERTEBRATES: III.—DIFFERENCE-THRESHOLD FOR BAND-WIDTH IN THE MONKEY AND THE DOMESTIC CHICK.*

By H. M. Johnson.

In the experiments reported in the above series of papers, the general procedure observed is that of the so-called " discrimination-method " of Professor R. M. Yerkes. In brief, the animal is placed in a chamber in which his movements may be controlled and observed, and allowed to obtain food in one of two food-compartments. The entrance to each compartment is marked with a visual object. These objects are mutually interchangeable, and may be made to differ in any physical characteristic—*e.g.*, area, outline, brightness, color, etc. One of these objects, the " positive stimulus," indicates the food-compartment to be chosen; the other, called the " negative stimulus," indicates the food-compartment to be rejected. If the animal chooses the box indicated by the negative stimulus he receives a light electric shock, automatically given. The left-right position of the stimuli is determined by a pack of shuffled cards containing an equal number of reds and blacks. Numerous well-known precautions described in Papers 1 and 2 of this series † are taken to prevent other factors than the visual stimulus difference under study from becoming effective.

In the beginning of the work on a given problem the stimulus-difference is made sufficiently large for the animal to acquire a " perfect discrimination-habit "—*i.e.*, of choosing the positive stimulus in 90 per cent. to 100 per cent. of a large number of trials. The difference is then decreased by very small steps until a point is found where the percentage of correct choices is about 75—*i.e.*, where the stimulus-difference is effective in half the total number of cases. This point is called the animal's threshold.

In the present work the stimuli are prepared by two Ives-Cobb visual acuity test-objects, so constructed as to present two fields, respectively, equal in area, outline, color, and mean brightness. Each field is covered by a system of alternate dark and bright striæ, respectively, equal in width, and the width and direction of the striæ may be independently varied.

---

* To appear in *Journal of Animal Behavior.*

† *Journal of Animal Behavior,* vol. 4, p. 319 ff., 1914.

In a preliminary experiment the direction of both systems was made horizontal, and the width of each band on the negative field was made about 0.1 mm. (The animal was restrained from bringing the eye nearer than 60 cm. from the test-object, at which distance the negative field was of sensibly uniform brightness to the human eye.) Each of the bands on the positive field was made 2.23 mm. wide until a perfect discrimination-habit was established, after which band-width was reduced by small steps until the threshold was found for each animal. For the one Capuchin monkey used in this work this value was 0.163 mm., each band subtending a visual angle of 57″. (The mean value obtained for five photometrists was 49″, with an individual mean value of 2 per cent. to 4 per cent.) For two Indian game cocks the band-width was a little over 0.7 mm., subtending a visual angle of a little over 4′ at the distance given. Two dogs failed to establish a discrimination-habit, although the band-width on the positive field was about 4 mm. These results served to determine the range of stimulus-values in which the present tests could be made.

In the work herein reported both systems of striæ lay in the horizontal direction, and the band-width on each field was above the animal's stimulus threshold; stimulus-difference under study was the band-width and conversely of number in the positive and negative systems, respectively. The animals were fed at the coarser system and shocked at the finer system.

Chick 1 failed to learn the problem. He succeeded, however, in maintaining perfect discrimination when the two systems were opposite in direction and also different in band-width, but he failed when either factor was eliminated.

Chick 2 was tested at six points between absolute band-width of 3.1 mm. and 0.74 mm. The thresholds yielded varied between 33 per cent. and 42 per cent. of the value of the "standard" stimulus. No consistent rule of variation was discovered.

The monkey was tested at seven points for the "upper" and "lower" threshold values, between 1.561 mm. and 0.173 mm. His results are quite consistent. At the standard stimulus-value 0.312 mm. the threshold was less than 3 per cent.; at 0.223 mm., about 5 per cent., and at 0.191 mm., 9 per cent. At stimulus-values larger than 0.312 mm. the thresholds were much larger, but they were obtained in the early stages of experimentation, and a later test revealed that the differences were due to a practice-effect.

A subsequent test gave a mean of the upper and lower thresholds at standard stimulus—0.780 mm. of less than 3 per cent.

The final values given by the monkey, when plotted against stimulus-values, gives curves which closely approximate those yielded by two human subjects, in rather rough tests, made under identical visual conditions.

A discussion of these results in the light of comparative anatomy and physiology will be attempted in a later paper.

Polluted Farm Waters. (*U. S. Geological Survey,* Water Supply Paper 255.)—In selecting a country home for the summer special attention should be given to the question of a pure water supply. Farms, which are generally remote from towns, cities, or other areas of congested population, seem to be almost ideally situated for obtaining pure and wholesome water. In reality, however, polluted water is exceedingly common on farms, and typhoid-fever rates are usually greater in country districts than in cities. Typhoid fever is transmitted largely in drink or food taken into the stomach, and is especially likely to be communicated by polluted waters obtained from shallow wells near spots where the discharges of typhoid patients have been deposited and subsequently carried into the wells, and it is doubtless principally this fact that makes the disease so common in farming regions.

The sources of the water used on the farm are numerous—lakes, streams, springs, wells of various kinds, and cisterns—all being extensively used, although the water from lakes and streams is generally used only for stock. Each of these sources under some conditions may yield entirely safe and satisfactory supplies, while under other conditions certain of them may be a constant menace to health.

Of the various sources of water supply, the ground water is the most satisfactory for farm use, because it is least liable to pollution, and streams and pools are the most unsatisfactory, because of the ease and frequency with which they are contaminated. Fortunately, however, they are very seldom used for drinking and domestic purposes, being utilized mainly for stock, on which the effect of slight general pollution is not serious, though some severe epidemics of disease among cattle have been traced to polluted streams. The underground supplies, whether from wells or springs, although safe in many localities, are far from being universally so, the safety depending mainly on their location and on the nature of their protection.

Many of the failures to protect adequately the water supplies used for drinking arise from a lack of knowledge of the manner in which waters circulate through the ground and of the ways in which they may become polluted.

THE FRANKLIN INSTITUTE

RESOLUTIONS ADOPTED BY THE BOARD OF MANAGERS ON THE OCCASION OF THE DEATH OF JOHN BIRKINBINE.

PHILADELPHIA, July 1, 1915.

The Board of Managers of The Franklin Institute, deploring the passing away of its honored member, the former president of the Institute, JOHN BIRKINBINE, unanimously resolves to place on record in the minutes of the Board, as an expression of regard and esteem by his associates, this present memento of the manifold services rendered by John Birkinbine to The Franklin Institute during the fifty years of his active participation in its work.

The Board further resolves that this memorial be published in the JOURNAL of the Institute and that a copy thereof be engrossed and transmitted to the family of its departed member.

RESOLUTIONS ADOPTED BY THE COMMITTEE ON SCIENCE AND THE ARTS ON THE OCCASION OF THE DEATH OF RICHARD GILPIN.

PHILADELPHIA, July 1, 1915.

The Committee on Science and the Arts of The Franklin Institute, sensible of the loss which its membership has sustained through the untimely death of RICHARD GILPIN, on June 21st, unanimously resolves that there be recorded in its minutes this present memorial of the faithful service rendered by Richard Gilpin as member of this body during the past eleven years, in recognition of his efficient collaboration as a technologist, and in appreciation of the sterling qualities of his genial personality.

The committee further resolves that this minute be published in the JOURNAL of the Institute and that an engrossed copy thereof be transmitted to the family of the deceased.

MEMBERSHIP NOTES.

NECROLOGY.

George Ormrod was born in Preston, England, on July 13, 1839, and died at Allentown, Penna., on June 21, 1915.

He came to the United States when nineteen years of age, and on the death of his uncle, William Donaldson, became superintendent of the latter's colliery at Tamaqua, Pa. Later he was associated with his father-in-law in the operation of a colliery, and from 1865 to 1877 operated, with several others, the Girard Colliery at Raven Run. Mr. Ormrod was also connected with St. Nicholas Coal Company, Mahanoy City, as director and president, and the Kehley Run mine at Shenandoah.

In 1880 he leased the Emaus Blast Furnace for the purpose of manufacturing pig iron, and three years later established the Emaus Pipe Foundry for the manufacture of cast-iron pipe. The latter firm was incorporated in 1886 as the Donaldson Iron Company and has been in continuous operation for over thirty-five years, Mr. Ormrod serving as manager and treasurer and later as president.

With his son-in-law, Mr. Ormrod organized the first Portland cement plant in New Jersey in 1893, and in 1897, with several others, organized the Lehigh Portland Cement Company.

Mr. Ormrod was active in numerous charitable organizations, clubs, and societies.

He became a member of The Franklin Institute in 1905.

Richard Gilpin, 904 Clinton Street, Philadelphia, Penna.

LIBRARY NOTES.

PURCHASES.

AGRICOLA, GEORGIUS.—De re metallica. Translated from the first Latin edition of 1556 by H. C. and L. H. Hoover. 1912.

BAUSCHINGER, J., and PETERS, F., ed.—Logarithmic-trigonometrical Tables. 2 volumes. 1911.

BROWN, JAMES CAMPBELL.—Essays and Addresses. 1914.

DALL, WILLIAM H.—Spencer Fullerton Baird—A Biography. 1915.

DAVEY, NORMAN.—The Gas Turbine. 1914.

DUNBAR, SEYMOUR.—History of Travel in America. 4 volumes. 1915.

FRIEND, J. N., and others.—Text-book of Inorganic Chemistry, volume i, parts 1 and 2. 1914.

GASTER, LEON, and DOW, J. S.—Modern Illuminants and Illuminating Engineering. 1915.

GIOLITTI, FEDERICO.—Cementation of Iron and Steel. 1915.

HAYES, HAMMOND V.—Public Utilities, their Fair Present Value and Return. 1915.

HERO.—Di Herone Alessandrino de gli Automati onero Machine se Moventi, Libridue, Tradotti dal Greco da Bernardino Baldi Abbate di Guastralla. Venice, 1589.

HUBBARD, C. L.—Combined Power and Heating Plants. 1915.
JEANS, J. H.—Mathematical Theory of Electricity and Magnetism. 1911.
JERVIS-SMITH, F. J.—Dynamometers. 1915.
London Chemical Society.—Annual Report, volume xi. 1914.
MILLS, A. P.—Materials of Construction. 1915.
NOEBELS, SCHLUCKEBIER, and JENTSCH.—Telegraphie and Telephonie. 1901.
PEARSON, KARL, ed.—Tables for Statisticians and Biometricians. 1914.
PEEK, F. W. J.—Dielectric Phenomena in High-voltage Engineering. 1915.
RAMELLI.—Le Diverse et Artificiose Machine del Capitano Agostino Ramelli dal ponte della tresia Ingegnerio del Christianissimo Re di Francia et di pollonia. Nellequali si contengono narij et industriosi Monimenti, degni digrandissima Speculatione per cauarne beneficio infinito in ogni forte d'operatione; Composte in lingua Italiana et Francese. Paris, 1588.
SCHOTT.—P. Gasparis Schotti, Technica Curiosa sive Mirabilia Artis Libris xii comprehensa quibus varia Experimenta, variaque Technasmata Pneumatica, Hydraulica, Hydrotechnica, Mechanica, Graphica, Cyclometrica, Chronometrica, Automatica, Cabalistica. Nuremberg, 1664.
TARTALEA.—Quesiti et Inventioni diverse de Nicolo Tartalea Brisciano. Venice, 1543.
WILLIAMS, H. E.—Chemistry of Cyanogen Compounds. 1915.

GIFTS.

American Institute of Mining Engineers, Transactions, vol. xlix, 1914. New York, 1915. (From the Institute.)
Amherst College, Obituary Record. Amherst, Mass., 1915. (From the College.)
Baylor University, Catalogue. Waco, Texas, 1915. (From the University.)
Bourne-Fuller Company, Tool Steel and its Uses. Cleveland, no date. (From the Company.)
Brown and Sharpe Manufacturing Company, Catalogue No. 26 of Small Tools, General Catalogue of Machinery and Tools. Providence, R. I. (From the Company.)
Canada Board of Railways Commissioners, Ninth Report, 1914. Ottawa, 1915. (From the Commission.)
Canada Department of Mines, Memoir 53, Coal Fields of Manitoba, Saskatchewan, Alberta, and Eastern British Columbia, 1914; Memoir 64, Preliminary Report on the Clay and Shale Deposits of the Province of Quebec, 1915; Memoir 57, Corundum, its Occurrence, Distribution, Exploitation, and Uses, 1915. Ottawa, 1914–15. (From the Department.)
Canadian Archives, The Canadian North-West. Ottawa, 1915. (From the Archivist.)
Cincinnati Gear Cutting Machine Company, Catalogue A of Gear Cutting Machinery. Cincinnati, no date. (From the Company.)
Connecticut State Board of Agriculture, Annual Reports, 1899, 1901, 1902, 1907 to 1913. Hartford, 1900–1914. (From the Board.)
daCunha, A., L'Annee Technique. Paris, 1905. (From the Philadelphia Book Company.)

Engineers' Society of Pennsylvania, Year Book, 1915. Harrisburg, no date. (From the Society.)

Goodrich, B. F., Company, Motor Trucks of America, vol. 3. Akron, Ohio, 1915. (From the Company.)

Indian Meteorological Department, Memoirs, vol. xix, parts v and vi. Calcutta, 1915. (From the Superintendent of Government Printing.)

Industrielle Gesellschaft von Mulhausen, Jahresbericht, 1914. Strassburg, 1915. (From the Society.)

Jeffrey Manufacturing Company, General Catalogue No. 83 of Power Transmission Machinery for the Mill, Factory, and Mine. Columbus, Ohio, no date. (From the Company.)

Kansas State Board of Agriculture, Nineteenth Biennial Report, 1914. Topeka, 1915. (From the Department.)

Lansing Company, Catalogue No. 11 of Concrete Mixers, Hoists, Skids, etc. Lansing, Mich., no date. (From the Company.)

Lewis, E. St. Elmo, Efficient Cost Keeping. Detroit, 1914. (From the Burroughs Adding Machine Company.)

Massachusetts Gas and Electric Light Commissioners, Report, 1914. Boston, 1915. (From the Commissioners.)

Massachusetts Institute of Technology, May Bulletin, Boston, 1915. (From the Institute.)

Medford Water and Sewer Department, Annual Report, 1914. Medford, Mass., 1915. (From the Department.)

National Association of Cotton Manufacturers, Transactions, 1914. Boston, 1915. (From the Association.)

National Twist Drill Tool Company, Catalogue No. 9 of Carbon and High-speed Twist Drills. Detroit, no date. (From the Company.)

New Hampshire Public Service Commission, Reports, vol. 4, 1914. Concord, no date. (From the Commission.)

New York Public Service Commission for the First District, Annual Report, 1913, vol. ii; 1914, vol. i. Albany, 1915. (From the Commission.)

New York Public Service Commission, Second District, Annual Report, 1913. Albany, 1914. (From the Commission.)

Ohio Industrial Commission, Report No. 4 of the Department of Investigation and Statistics. Columbus, 1915. (From the Commission.)

Ontario Agricultural College and Experimental Farm, Fortieth Annual Report 1914. Toronto, 1915. (From the Department of Agriculture.)

Ontario Minister of Agriculture, Report, 1914. Toronto, 1915. (From the Minister.)

Ontario Women's Institutes, Report, part i, 1914. Toronto, 1915. (From the Department of Agriculture.)

Pennsylvania at Gettysburg, Fiftieth Anniversary Report of the Pennsylvania Commission, 1913. Harrisburg, 1914. (From the State Librarian.)

Pennsylvania State Treasurer, Annual and Detailed Reports, 1914. Harrisburg, 1915. (From the State Librarian.)

Pennsylvania Topographic and Geologic Survey, Reports, Nos. 7, 8 A, 8 C, 8 E, 1911; Biennial Report, 1914; Report No. 2, 1914. Harrisburg, 1914. (From Mr. Edward V. d'Invilliers.) Report No. 7. Harrisburg, 1913. (From the State Librarian.)

Philadelphia Free Library, Nineteenth Annual Report, 1914. Philadelphia, no date. (From the Library.)

Rensselear Polytechnic Institute Publications, Engineering and Science Series, 1, 3, 4, 5, 6, 7, no date; Catalogue. Troy, 1915. (From the Institute.)

Rhode Island Public Utilities Commission, Third Annual Report, 1914. Providence, 1915. (From the Commission.)

Royal Irish Academy, Proceedings, vol. xxxi, March and April, 1915. Dublin, Ireland, 1915. (From the Academy.)

Royal Society of South Australia, Transactions and Proceedings, vol. xxxviii, 1914; Memoirs, Chiastolites from Bimbowrie, South Australia, 1911. Adelaide, 1915. (From the Society.)

Safety on the Boston Elevated Railway. Boston, no date. (From Robert D. Jenks, Esq.)

Society of Naval Architects and Marine Engineers, Transactions, 1914. New York, no date. (From the Society.)

State College of Washington, Catalogue. Pullman, 1915. (From the College.)

St. Louis University, Bulletins and Catalogue. St. Louis, Mo., 1915. (From the University.)

Stone & Webster Engineering Corporation, Building Construction. Boston, no date. (From the Corporation.)

The Transit. Iowa City, 1915. (From the College of Applied Science, University of Iowa.)

United States Geological Survey, The Pleistocene of Indiana and Michigan and the History of the Great Lakes. Washington, 1915. (From the Survey.)

United States War Department, Annual Report of the Chief of Engineers, vol. ii. Washington, 1914. (From the Department.)

University of Arizona, Annual Catalogue. Tucson, 1915. (From the University.)

University of Idaho, Catalogue. Moscow, 1915. (From the University.)

University of Louisville, Catalogue. Louisville, 1915. (From the University.)

University of Michigan, Astronomical Observatory, Publications, vol. i, pp. 73–206. Ann Arbor, 1915. (From the University.)

University of Missouri Bulletin, Science Series, vol. 1, Nos. 1–9; vol. 2, Nos. 2, 3, 4. Columbia, 1911–1914. (From the University.)

University of Nebraska, General Catalogue. Lincoln, 1915. (From the University.)

University of Texas, Catalogue. Austin, 1915. (From the University.)

University of the State of New York, Education Department, Annual Report, 1914; Proceedings of the Inauguration of John Huston Finley, 1914. (From the State Librarian.)

University of Toronto, Calendar of Department of Applied Science and Engineering. Toronto, 1915. (From the University.)

Verein Deutscher Chemiker, Mitgliederverzeichnis, 1915. Leipzig, no date. (From the Society.)

Ware Brothers Company, The American Fertilizer Hand Book, 1915. Philadelphia. (From the Company.)

Wisconsin Geological and Natural History Survey, Bulletin No. 34, Limestone Road Materials of Wisconsin. Madison, 1914. (From the Survey.)

PUBLICATIONS RECEIVED.

U. S. War Department, Annual Report, 1914: Reports of the Secretary of War, the Chief of Staff, the Adjutant General, the Inspector General, the Judge-Advocate General, the Quartermaster General, the Surgeon General, the Chief of Ordnance, the Chief Signal Officer, the Chief of Coast Artillery, the Military Academy, Military Parks, Chief of Engineers, Chief Bureau of Insular Affairs, Governor of Porto Rico. 3 volumes, illustrations, plates, maps, tables, 8vo. Washington, Government Printing Office, 1915.

Engineers' Society of Western Pensylvania, Year Book, 1915. 95 pages, 16mo. Harrisburg, Pa., Society, no date.

Pennsylvania Topographic and Geologic Survey: Report No. 8, The Mineral Production of Pennsylvania, 1911. Coal and Coke. Petroleum and Natural Gas. Clay and Clay Products, Sand, Lime, Brick. Copper, Nickel, Iron Ore, Salt and Bromine, Abrasive Materials, Graphite, Feldspar and Quartz, Talc and Soapstone, Slate, Mineral Pigments, Cement, Sand and Gravel, Mineral Waters. Quarry Products, Granite, Trap Rock, Sandstone, Bluestone, Marble, Limestone, Lime. 275 pages, 8vo. Harrisburg, Pa., State Printers, no date.

U. S. Department of Agriculture: Bulletin 220, Road Models Prepared by the Office of Public Roads. 24 pages, illustrations, 8vo. Washington, Government Printing Office, 1915.

Safety and Short Trains, address by Marcus A. Dow, General Safety Agent, New York Central Lines. 30 pages, 12mo. No place, no date.

New York Stock Exchange in the Crisis of 1914, by H. G. S. Noble, president. 89 pages, 8vo. Garden City, Country Life Press, 1915.

Analysis of Milk and Milk Products, by Henry Leffmann, M.D. Fourth edition, revised and enlarged. 115 pages, illustrations, 12mo. Philadelphia, P. Blackiston's Son & Co., 1915. Price, $1.25.

500,000-volt Transformer of the Oerlikon Works. ANON. (*La Revue Electrique,* vol. xxiii, No. 271.)—The Oerlikon Works regularly manufactures testing transformers giving voltages of 200,000 and 250,000. For use in their own laboratories they have found it necessary to construct a transformer yielding in normal operation a difference of potential of 500,000 volts. The exterior shape of the apparatus is cylindrical, 3.3 m. in diameter and 3.6 m. high. Its total weight is 34 tons. It is capable of taking a current of 1000 ampères at 500 volts. At 500,000 volts the sparking distance is 1.32 m., and at its maximum overload, giving a voltage of 700,000, the sparking distance is 1.85 m.

CURRENT TOPICS

Precision Resistance Measurements. E. H. RAYNER. (*The Physical Society of London, Proceedings,* vol. xxvii, part iv.)—The paper describes methods by which the comparison of resistance can be made to an accuracy of 1 in 10,000 or higher by using simple apparatus usually available in electrical laboratories or which can be easily constructed with little skilled assistance. The comparison of nominally equal resistances of one ohm and upwards by the usual method of shunting one side of a nearly balanced quadrilateral by a high resistance is mentioned, and variations of this when only part of one resistance is shunted are often useful. The great advantage of having resistance capable of carrying comparatively large currents is illustrated, especially for measuring changes of resistance of commercial apparatus under working conditions. The determination of errors in a volt-box for use with a potentiometer is described at some length. This is of especial importance in precision photometry.

If a sufficient continuous-current voltage is not available for testing such apparatus as high-potential dividers, it is shown that, using sufficient continuous current to secure sensitivity, the heating may be supplied by superposed alternating current.

Resistances in common use are very generally of simple numerical value, and a Kelvin bridge specially designed for the comparison of such resistances is described. It consists essentially of two rows of 25 resistances of 20 ohms each.

The Change in Thermal Conductivity of Metals on Fusion. A. W. PORTER and F. SIMEON. (*The Physical Society of London, Proceedings,* vol. xxvii, part iv.)—The change in question was determined for mercury and sodium by finding the temperature at different points of a cylinder of the metal contained in a glass tube. The ends of the cylinder were maintained at such temperatures that the metal was liquid half way down its length, the remaining part being solid. The temperatures were taken by means of thermo-electric junctions inserted in narrow tubular depressions which had been formed in the glass tube by forcing a knitting needle down into the locally-heated glass. The ratio of the thermal conductivity for solid and liquid was estimated from the slope of tangents drawn to the temperature-curve on each side of the melting-point. The values of these ratios are of the same order as the ratio of the corresponding values of the electrical conductivities. The mean value for mercury is 3.91 and for sodium 1.31. A summary list is given of other data concerned with fusion.

On the Self-Induction of Solenoids of Appreciable Winding Depths. S. BUTTERWORTH. (*The Physical Society of London, Proceedings,* vol. xxvii, part iv.)—The existing formulæ for coils of this type—viz., those of Rosa and Cohen—are shown to be inaccurate, the error amounting to one-fifth of one per cent. for the best formula when the winding depth is one-tenth the diameter of the coil. For greater winding depths the error is larger. The inaccuracy in Rosa's formula is due to the neglect of curvature in correcting for thickness, while in Cohen's formula the error is due to the approximate method of development.

New formulæ are developed by methods which are free from such approximation and which apply to any coil for which the length is greater than twice the diameter and the winding depth less than one-tenth the diameter. These formulæ are capable of giving eight-figure accuracy. Simplified formulæ are given which are suitable when only four-figure accuracy is required.

The Kodachrome Process of Color Protraiture. ANON. (The *British Journal of Photography,* vol. lxii, No. 2870.)—From time to time fragmentary reports have appeared of progress in the development of a simplified method of producing photographs in color by the now well-known color filter process in the hands of the Eastman Kodak Company. In a paper read before the Royal Photographic Society, from which the following outline is abstracted, the technical steps involved in the production of the Kodachrome transparency are given in detail:

An obvious step towards simplification in the making of prints and transparencies by the subtractive method of color photography would be the substitution of two colors for three. This has already been done in the "Kinematicolor" additive process of color cinematography where two negatives are used—a red and a green—and positives from these are projected alternately upon the screen, through red and green filters. The color rendering in this process is quite pleasing, although the correctness is much inferior to that of the three-color process, but the results obtained are sufficiently encouraging to justify the belief that a slight improvement in color rendering over the results obtained by this two-color additive process would be quite satisfactory for many purposes.

The method adopted is to make the negatives on specially-prepared panchromatic plates and through the correct filters, and then to develop them as usual. They are then chemically treated so as to remove the black silver and leave the plate looking just like a colorless sheet of gelatine, showing no sign of an image. When this plate is put into the specially-prepared dye bath the dye goes into the gelatine most easily when the silver is absent in the negative; that is, when there is least light in the original photograph or in the part represented by deep shadows, while in the parts corresponding to the highlights, when there is much silver in the negative, the dye penetrates more slowly, so that as the dye slowly enters the film the original negative is transformed into a positive produced in a colored dye. While one color is made in this way, the companion picture is also dyed in the other color, and the two, when placed together, make the finished picture. Since only two colors are used in the process, it is obvious that all colors cannot be correctly rendered, and the colors for which the process fails are the blues, violets, magentas, and purples. Light blues appear blue-green and violets, black; magentas appear pink, and purple, dark brownish-red. On the other hand, flesh tints of all kinds and all shades of red, orange or green, grays and blacks are well rendered. All these are predominant in portraits, and the results are very satisfying for this class of work. Portraits produced by this process are in the form of transparencies, and are intended to be viewed in a special illuminator. The pictures appear at their best when placed in the special illuminator, giving much truer color rendering than when viewed by daylight.

The process cannot be used for the production of paper prints, and in most cases it is convenient to transform the original negative into the finished positive, but, if desired, duplicates can be made from contact prints of the negatives. The new process, according to its inventors, is not well adapted in its present form to outdoor subjects, especially when blue sky is included. The limitation of the process to transparencies must also be remembered. It represents, however, a highly satisfactory and practical method of obtaining beautiful color portraits having first-rate photographic quality and giving a pleasing reproduction of the colors of the original.

Operating and Test Data for Fuel-oil Engine and Generator. R. B. WHITE. (*Electrical World,* vol. 65, No. 26.)—The very great economy that is possible to effect by the employment of the fuel-oil engine in electric light and power service is strikingly shown in the report on the performance of such an engine in the plant of the Goodland (Kan.) Light and Power Company. The oil engine is 60-horse-power, of the two-stroke semi-Diesel type for crude or fuel-oil, belted from the fly-wheel to a 75-kilowatt, three-phase, 2300-volt, sixty-cycle generator, operating single-phase at 2200 volts. This unit operates in parallel with a 100-kilowatt, single-phase generator driven by a 165-horse-power single-cylinder engine. The steam is generated from coal costing $3.25 per ton delivered. The oil engine uses Kansas fuel-oil costing 2.3 cents per gallon. Before installing the oil engine the coal bill was $600 per month, whereas the present coal and oil bill does not exceed $300 per month.

The Drop-weight Method for the Determination of the Surface Tension of a Liquid. J. L. R. MORGAN. (*Journal of the American Chemical Society,* vol. xxxvii, No. 6.)—This method for the determination of the surface tension is one of the results of the extended purely experimental and statistical investigation of the relationship between the falling drop weight and the surface tension of a liquid, reports of which have appeared from time to time from this laboratory (Chemical Laboratories of Columbia University). The drop weights considered throughout this work are those found by the aid of apparatus already described in this journal, which enables one to determine with a high degree of precision the weight of any desired number of drops of liquid falling from any sharp-edged capillary dropping tip at any fixed temperature below 90°, free from any effect of evaporation. As the result of an experimental study of some two hundred especially purified liquids and solutions, for more than one hundred of which the surface tensions (lying between 15.3 and higher than 76 dynes per centimetre) for purposes of comparison are known from some other method, of liquids which include those of every conceivable type and possessing every property which might adversely influence their behavior, it has been found that under certain definite conditions the drop weights of liquids from any one dropping tip are proportional to their surface tensions at the same temperature.

Potash from Kelp. (*Commerce Reports,* 1915, No. 143.)—The Bureau of Soils in the Department of Agriculture has issued a most timely and important monograph on the kelp beds in the Pacific, found off a large proportion of our littoral, including Alaska. The report in question bears the title "Potash from Kelp," and is prepared by Dr. Frank K. Cameron, who has the supervision of chemical, physical, and fertilizer investigations. It presents in compact form the results of an enormous amount of marine exploration and analytical work in the laboratory. Nothing has been omitted which is requisite for an adequate knowledge of the extent of the beds, the local characteristics, the percentage of potash and other valuable constituents present, the facilities for exploitation, and all other factors which may eventually come into play in any attempt to utilize on a generous scale the great possibilities of this magnificent national asset.

The Action of Certain Colloids on Ions during Electrolysis. A. MUTSCHELLER. (*Metallurgical and Chemical Engineering,* vol. xiii, No. 6.)—As early as 1885 it was recognized that the addition of certain substances to electroplating and refining baths had specific effects on the form and consistency of the deposit upon the cathode. Selections from those substances which improve the deposit were recognized to be colloids and, as a rule, of the amphoteric or reversible type. A further suggestion was found in the fact that the temperature coefficients on the rate of change of the migration velocity of the ions are such that they tend to make the velocity of the two ions equal as the temperature rises. Moreover, the form of the deposit itself, such as it is obtained from a sure electrolyte in the form of striæ or branches, was a sufficiently powerful inducement to a hypothesis that the regulation of the velocity of the ions should constitute the influencing factor in question. The experimental investigation leads to the general results that, if to a given concentration of an electrolyte, gelatine solution is added in a small quantity, the velocity of migration of the anions is decreased and gelatine, together with the absorbed anions, migrates to the anode. On increasing this addition, a point is reached where the gelatine-anion complex ceases to migrate, while the relative migration velocity of the cations has become equal to 1. If finally this addition is further increased, it is found that the complex gathers on the other electrode, the cathode, where it deposits with the metal.

Optical Pyrometers. C. R. DARLING. (From " The Measurement of High Temperatures," *The Engineer,* vol. cxviii, No. 3078.)—In connection with the recent work on radiation pyrometers and their calibration, it is of interest to recall the views of Sir Robert Hadfield on the subject:

Measurement of temperature from a distance by means of radiation or optical pyrometers fails for two chief reasons: *First,* the temperature of the surface on which the instrument is sighted is lower than that of the interior, even in the case where no oxidation occurs and no slag is present. In practice the presence of oxide or slag in layers of varying thickness renders it impossible to establish any fixed relation between the temperature of the surface and the true internal temperature, and hence concordant results can not be obtained. *Second,* when fumes are rising from the ladle, as is frequently the case with alloys, the radiations received by the instrument are seriously diminished, and the reading, even if otherwise reliable, would be too low on this account. These difficulties have been partially overcome by Whipple's modification of Féry's radiation pyrometer described by the writer in the *Engineer* for June 13, 1913, in which the pyrometer is permanently mounted at the open end of a fire-clay tube so as to be focussed on the closed end, which is inserted in the molten metal. This method, while suitable for crucibles and small ladles, can not be applied to large masses, as the readings would be affected by the intense heat existing in the vicinity of the pyrometer. The solution of the problem, therefore, appears to lie in some suitable application of the thermo-electric or resistance methods of measuring high temperatures.

Inorganic Fodder.—ANON. (*Scientific American,* vol. cxiii, No. 1.)—Germany possesses abundant supplies of potatoes, beet roots, and turnips; that is, materials holding carbohydrates. Albuminous fodder, on the other hand, is available only in limited quantities. Now an invention recently made at the Institute of Fermentation Industries, Berlin, will, it seems, allow a nourishing yeast, containing more than fifty per cent. of albumin, to be prepared from sugar and ammonium sulphate. Sugar is, to this effect, bound to an organic base; in order to supply the albumin so far wanting, the sugar is " fertilized " with ammonia, potash, and magnesia in the form of their salts, after which some yeast is introduced and a strong air current applied. The yeast then absorbs the sugar and the "fertilizer," thus resulting in the formation of a highly albuminous yeast.

The process above outlined, of course, can be used only in such countries as are amply provided with sugar and ammonia. Germany, as is well known, raises much beet sugar, while Dr. Haber's synthetic process enables ammonia in any amounts to be prepared from nitrogen and hydrogen. The dry yeast obtained according to the above process constitutes an excellent nourishing fodder for cattle, and especially for horses. It is now prepared in existing press-yeast factories, but will shortly be manufactured in large works erected for the purpose.

The Inflammable Limits of Mixtures of Gasoline Vapor and Air. G. A. BURRELL and H. T. BOYD. (*The Journal of Industrial and Engineering Chemistry,* vol. 7, No. 5.)—Gasoline is so widely used in internal-combustion motors and for other purposes that the limits of complete inflammation in mixtures of its vapor and air are of interest to users of gasoline generally. Using a 100 Cc. Kempel explosion pipette, and igniting the mixtures from the top, there was obtained as the lower limit of complete inflammation a value lying between 1.9 and 2.0 per cent. of gasoline vapor. The upper limit under these conditions was found to be between 5.2 and 5.3 per cent. of gasoline vapor. The gasoline used had a specific gravity of 73° Baumé. Under the same conditions, except ignition of the mixtures from the bottom, there was obtained a value lying between 1.5 and 1.6 per cent. of gasoline vapor or the low limit. With the same grade of gasoline, using a 2800 Cc. vessel and with ignition from the bottom, by means of an electric flash produced by pulling two wires apart through which a current of 7 ampères at 220 volts was flowing, there was obtained a value lying between 1.4 and 1.5 per cent. gasoline vapor. The high limit under these conditions lay between 6.0 and 6.4 per cent. of gasoline vapor. Appreciably different limits were not obtained with cleaners' naphtha. When the initial temperature is increased before igniting the mixtures, the low limit is gradually decreased until, with an initial temperature of 400° C., the low limit lies between 1.02 and 1.22 per cent. of gasoline vapor.

PRESS OF
J. B. LIPPINCOTT COMPANY
PHILADELPHIA

JOURNAL
OF
THE FRANKLIN INSTITUTE
DEVOTED TO SCIENCE AND THE MECHANIC ARTS

VOL. CLXXX SEPTEMBER, 1915 No. 3

MECHANICAL STOKING OF LOCOMOTIVES.*

BY
W. S. BARTHOLOMEW,
President, Locomotive Stoker Company, Schenectady, N. Y.

It gives me more than ordinary pleasure to have this opportunity to speak upon the subject of " Mechanical Stoking of Locomotives " before this audience and under the auspices of The Franklin Institute of the State of Pennsylvania, because those of us in commercial and industrial activities are usually accused of having an ulterior motive when we speak upon the subjects in which we are personally interested, and the privilege of having an audience disinterested from the purely utilitarian standpoint is much appreciated, and I hope to make the subject of interest of itself. I am therefore more than happy to be permitted to speak plainly upon phases of the Locomotive Mechanical Stoker problems, which are ordinarily held in the background, especially so because The Franklin Institute stands committed to encourage the application of mechanical and scientific principles which, by their use in industrial pursuits, may in some measure relieve the stress of physical labor when arduous, conserve energy, or add to the wealth of the individual, community, or nation, by effecting economies in any direction.

I shall therefore try to approach the subject of the evening

---

* Presented at the stated meeting of the Institute held Wednesday, April 21, 1915.

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

Copyright, 1915, by THE FRANKLIN INSTITUTE.

from the point of view of your honored institution, free even from what our legal friends would term "implied bias."

The firing of a steam locomotive with what in common railroad parlance is known as a "scoop" is about as crude a process as can be imagined, and has not changed very much in arrangement or method since locomotives were first used, and I shall take the liberty of assuming your entire familiarity with this hand-firing practice and also the continual increase in the size of locomotives during the past twenty or more years, and will refer mainly to locomotives in general service to-day, rather than to those in use when experiments with mechanical stokers first began.

There are something over three thousand patents on record covering mechanical stokers for locomotives, some of which were intended by the inventors to be suitable for use on stationary boilers as well. This does not include a still greater number of patents taken out on devices in connection with the firing of locomotives and stationary boilers with finely ground or pulverized fuel. This large number of patents will illustrate the difficulty of attempting to give any complete history of the development of the mechanical stoker for locomotives within the limits of this paper, and I shall therefore mention only some of the different angles from which inventors have approached the proposition.

Nearly all of the earlier inventors apparently had one object clearly in mind, and that was to fire a locomotive by machinery, not particularly for the purpose of reducing the fireman's labor, but to make it possible to use a helper, or common laborer, on the fireman's side of the locomotive in lieu of the regular fireman. This is well illustrated by the fact that with nearly all of the early stokers the operator was still required to actually shovel all of the coal into the stoking machine. The stoker was to do the work of putting the coal into the firebox and distributing it, the man was to be protected somewhat from the heat of the firebox, but the labor of shovelling the coal still remained.

It will readily be seen that such inventors were building their structure upon a false basis in assuming that stokers would be applied to any large number of locomotives for the simple purpose of reducing the grade or the class of labor and entirely overlooking the long-established practice of recruiting the engineers needed for the right-hand side of the locomotive from the firemen who have served their time and secured partially a locomotive engineer's experience through their years of service on the left-hand side of the locomotive.

Other inventors seemed to have in mind, as the main object for the use of a mechanical stoker on a locomotive, the preparation of the coal, and elaborate arrangements were made in the matter of crushing mechanism to handle lumps of coal twelve inches in diameter and over, so that the fireman would not be required to touch the coal in the coal-pit, and, having accomplished this, insufficient attention was given to the matter of putting the coal into the firebox and properly distributing it.

Several inventors brought out very elaborate devices for distributing the coal over the fire-bed, without making any arrangements whatever for the preparation of the coal or the conveying of the coal to the distributing mechanism.

Other inventors fully appreciated the arduous work of a locomotive fireman and the intense heat he is called upon to endure during the summer months under certain operating conditions, and were earnestly endeavoring to develop a locomotive stoker which would relieve the fireman from a large part of his physical labor and make it unnecessary for him to undergo the suffering due to the heat.

Some inventors confined their efforts exclusively to the proposition that the mechanical stoker would be a fuel-saving device. This was particularly true as to inventions in England and on the continent of Europe, where the cost of locomotive fuel is several times as much per ton as with us. Locomotives are being fired in Greece, for instance, with coal costing $12 per ton.

In the main, these experiments were along the conventional lines of hand-firing practice; that is to say, the delivery of the coal to the firebox in charges of fifteen to twenty pounds, as with a hand scoop, and the putting in of a "fire"; that is to say, a quantity sufficient for a period of more or less length, according to the way the locomotive was worked.

A few inventors, two in particular, whose inventions will be described later in this paper, were approaching the problem from an entirely different angle than the earlier history of the art disclosed, namely, to bring out machines which would assist the regular fireman in firing the locomotive in a better way and to a higher point of efficiency or to a greater horse-power output than was possible to do with hand firing, and at the same time do all that other inventors had done, or even go further in the matter of relieving him from physical labor and discomfort, or exhaustion.

It is only within the past three or four years, particularly the last three years, that mechanical stokers for locomotives have been brought out which included all necessary features to successfully meet the present operating conditions on large locomotives and be worthy of application in a large way.

Considering the mechanical stokers which have been applied and are still in use on locomotives, we may properly divide them into two general classes, namely, those which feed the coal to the firebox up through the fire-bed, and are commonly referred to as underfeed stokers, and those which feed the coal to the firebox over the top of the fire-bed, and are usually referred to as overfeed, or scatter type of stoker.

The underfeed stokers are of two types: those which feed the coal through the fuel troughs underneath the fire-bed with plungers, and those which distribute the fuel in the troughs with helicoid screws.

The overfeed stokers are more miscellaneous in character: There are those which distribute the coal over the fire-bed with plungers or other mechanical means, with steam jets without other directing means, and with steam jets with stationary directing means, and also with steam jets supplemented by movable mechanical directing means; also with steam jets having constant blast and with steam jets having intermittent blast; and both the underfeed and overfeed stokers might again be subdivided into those which supply the fuel intermittently to the firebox, putting in what the firemen call a fire or "slug" and then waiting for its consumption before another operation takes place, and those stokers which supply coal to the fire constantly in proportion to the rate of combustion.

There are conveyors for both the underfeed and overfeed stokers which have reciprocating action, supplying the fuel in separate charges to the stokers and those which carry the coal constantly to the stokers. Some of these conveyors are of the pusher type, which force the coal forward by pressure, and others carry the coal through its entire travel in a free and loose state.

Where preparation of the coal is attempted, it is usually done through the means of some part of the conveying mechanism, although in the early development of the stokers separate crushing machines were supplied, which, in turn, delivered the crushed coal to the conveying mechanism.

Counting all kinds of stokers which were applied to locomotives up to the year 1912, probably more than twenty-five different designs of stokers, widely variant in character, were put into service, and, strange as it may seem, *all of them fired the locomotives successfully, under certain conditions.* This peculiarity of the proposition led up to there being much misinformation circulated about the mechanical stoker for locomotives.

Some of this was also brought about by the promoters of the first stokers making unwarranted claims as to the machines being automatic, using this term even to the extent of certain companies being incorporated with the word "automatic" in their title.

This use of the word "automatic" brought immediate and very active opposition to the stoker on the part of the firemen, both individually and collectively, as they expected the "Iron Firemen" to supersede them, their wages to be reduced and their places taken by common laborers.

This fairly represents the locomotive stoker situation up to the end of the year 1911, as, notwithstanding the application of the many different kinds of stokers to locomotives in a comparatively short time, and the current reports that they were all wonderfully successful, no stokers of any consequence had been sold to the railroad companies in what could be considered a commercial way.

The American Railway Master Mechanics' Association had in the meantime appointed a Standing Committee on Mechanical Stokers for Locomotives, and several of the railroad companies also sent out committees to make investigations. The very intelligent and painstaking work of those committees contributed much to the development of stokers suitable to meet the conditions of operation obtaining on our larger locomotives of to-day, and the findings of the different stoker committees are of especial interest as an explanation of why large numbers of stokers were not applied prior to the middle of 1912, and also to forecast the characteristics of the present commercially successful locomotive stokers.

The summing up of the committees' reasons given for the non-application of stokers to locomotives in any great numbers is about as follows:

1. That most, if not all, of the locomotive stokers applied

up to the end of the year 1911 were not suited in one or more particulars to meet the variables in fuel, locomotives, and operating conditions, notwithstanding the fact that all the stokers applied up to that time actually had *bona fide* records of successful trips under certain conditions.

2. That practically all such stokers had been designed without due consideration having been given to the unusually severe requirements imposed upon strength of parts and correct mechanical design by the stress of operating conditions and the lower maintenance standards obtaining in railroad as compared with industrial service.

3. That the size of locomotives, particularly as to grate area and the tonnage hauled per train under the existing conditions of service up to the end of the year 1911, did not make mechanical stokers an absolute necessity.

4. That there was no evidence available to lead to the conclusion that a mechanical stoker would make it possible to fire a locomotive any more economically than with hand firing when the same amount of work was performed by the locomotive in each case.

5. That no advantage was being taken, to any appreciable extent, of the fact that, with mechanical stokers, large locomotives might be operated nearer to their maximum rated capacity than when hand-fired.

6. That nothing had developed up to that time to indicate that any less expensive fuel could be used for firing locomotives with a mechanical stoker than with hand-firing.

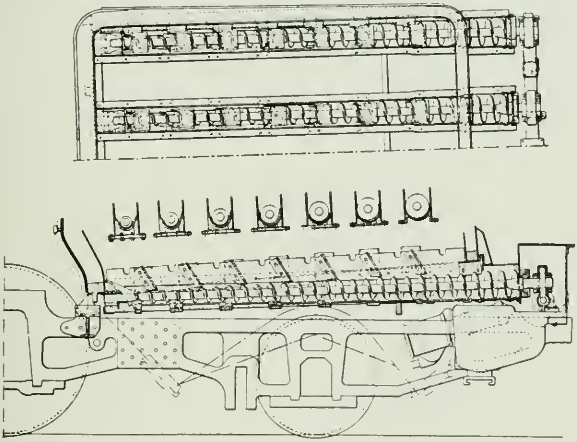
7. That it would not be possible, as claimed by some of the stoker inventors and promoters, to do away with the regular locomotive fireman and have the work done by a helper.

8. That labor-saving devices are not usually applied to any great extent simply to reduce the grade of or character of the labor—nor are they put into general use solely for the purpose of uplifting the grade and character of employment.

9. That therefore the only consideration left as an argument for the general application of mechanical stokers to modern locomotives was the possible reduction in the amount of physical labor and suffering of the regular fireman sufficiently to enable him to do the work without other relief.

A review of the history of the exploitation and introduction of a large number of labor-saving devices discloses the fact, regrettable as it may seem to have to admit it from a humanitarian standpoint, that most labor-saving devices are not applied generally unless there is some remunerative return to the purchaser, outside and apart from the ethical considerations; that is to say, there must be some increase in efficiency, some conservation of energy, some contribution to the wealth of the individual or the community at large, or the device must fail.

It is my intention to try to make it very plain that while the application of mechanical stokers to our large freight and passenger locomotives will, in fact does, effect a very great relief to the firemen from the strenuous labor incident to shovelling coal at the rates required to fire locomotives, photographs of which will be shown upon the screen to-night, and that the firemen are almost entirely relieved from the suffering due to the heat effects of having the fire door open when hand firing, yet these benefits are only incidental to the main issues which contribute to the necessity for, or economy of, the application of stokers to locomotives.


Plan view of Barnum underfeed stoker.

Counting all stoking machines applied to locomotives up to April 1st of this year, there have been about 1200 put into service, of which about 1000 are now in use. This number is divided as follows:

1 Gee stoker—overfeed type.
20 Standard stokers—overfeed type.

20 Hanna stokers—overfeed type.
365 Crawford stokers—underfeed type.
600 Street stokers—overfeed type.

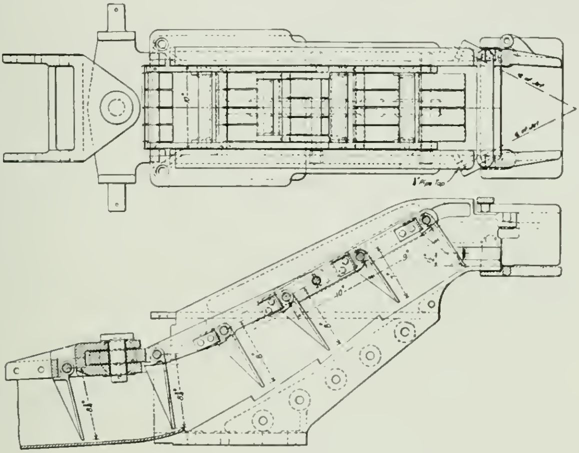
The 200 stokers applied at one time or another and later removed were not of these makes, with a few minor exceptions.

Before proceeding further with the general aspects of the subject, I should like to have you familiar with the details of these machines and some of the locomotives on which they are in use.

This is a plan view of the Barnum underfeed stoker. This was one of the stokers applied to locomotives experimentally and later on removed. One of the other slides will show the locomotive to which this stoker was applied. This stoker is of the underfeed type, having two or more stoking troughs placed longitudinally of the firebox. This drawing shows seven of the stoking troughs, but only three or four were used in the actual installations. The troughs were supplied with cast-steel helicoid screws, the flights of which were reduced in size at different points in their length, each diameter being about two feet long, and at the offset, where the reduction in flight took place, deflectors or partial partitions were provided, with an aperture equal only to the next reduced diameter of the flight of the screw. The effect of the use of these deflectors was to cause the coal to be lifted up out of the stoking troughs and forced over on to the grate areas at each side, and, of course, part of the coal was carried on through the reduced openings in the partitions until the next deflector was reached, where more coal was deducted from the quantity being forced along in troughs, and this continued until part of the coal had been carried to the extreme forward end of the firebox and forced up out of the trough by the bottom being slightly inclined upward. These stokers were operated by the use of two double-acting steam engines, one placed on each side of the locomotive at the end of the cross shaft. The screws were driven with worm drive, the worms being on the cross shaft and the worm wheels being at the back end of the cast-steel screws. Separate crushers of ample capacity were placed on the locomotive tender to prepare the coal.

Seven or eight of these stokers were applied and at least four or five of them saw considerable service with quite a number of different kinds of fuel and on locomotives of different types, at least one each being applied to a Switch, a Prairie, a Mikado, and a Decapod type of locomotive.

The results in service were quite satisfactory when the conditions existed which were favorable to the use of this kind of a stoking machine, and many successful trips were made with these stokers, taking the average of which it could probably be said that 75 per cent. of the coal burned on the trips made was fired by the stoker. The difficulty with this particular machine was probably more from mechanical shortcomings than from any inherent defects in the general scheme, although the results were not equally satisfactory with all kinds of coal used. It will be readily appreciated that, with the method used in firing with this stoker, there would not be the flexibility of control of the fire that will be noted with other stokers which will be shown and described.

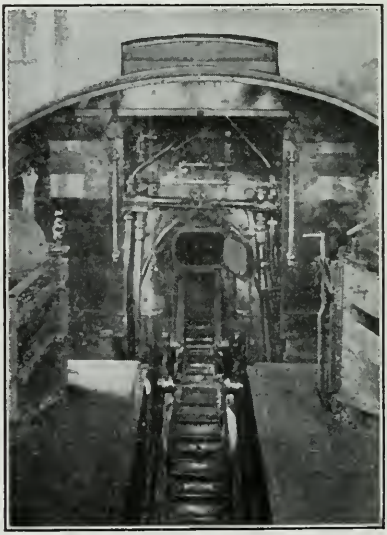


Plan view of Gee overfeed stoker.

This is a general plan view drawing showing the forward part of the conveying mechanism of the Gee overfeed scatter type of stoker and also the movable directing wings which are placed above the firing plate at the bottom part of the ordinary fire door. One of these stokers has been applied to a consolidation locomotive on the Pennsylvania Railroad, and is in operation in regular service to-day, firing the locomotive successfully. A crushing mechanism is placed at the back part of the conveyor of this stoker, which also serves as a measuring or feeding device to start the coal into the forwarding means of the conveyor.

This view also shows a cross-section of the forwarding vanes of the conveyor. These are not made all in one piece, but are practically fingers which drop back of the coal in the backward movement of the reciprocating conveyor and serve to push part, or all, of the coal in their vicinity forward, to be engaged by the next succeeding set of fingers in the following action of the conveyor. The reciprocating action of this type of conveyor accomplishes the purpose not only of forwarding the coal but of partially measuring it and serving it to the firing plate in separate charges, and the steam blasts are operated in timed relation to the forwarding of these separate charges of fuel, and serve as plungers to inject the coal into the firebox in very much the same manner as it would be fired with a scoop.

The direction of these separate charges of fuel to the different parts of the firebox is accomplished by the movement of the wings, in relation to which the jets are also controlled, so that when the wings are pointed toward the left-hand side of the firebox the jet on that side is shut off and the right-hand jet serves to force the charge of fuel in conjunction with the wings over to the left-hand side of the firebox, and so on.



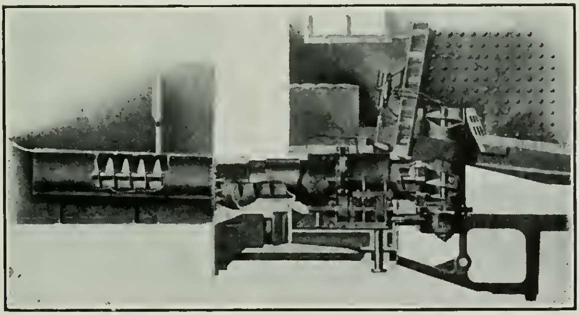
Photograph of general view of Gee stoker applied to locomotive and tender.

This is a photograph showing the general view of this stoker and with the deck of the tender and locomotive removed, so that the conveyor can be seen almost through its length. The crushing mechanism is just back of that part of the conveyor shown in the lower margin of the photograph. The position of the stoking mechanism itself, just below the fire door, can be readily observed in this view.

This stoker is operated by means of a steam cylinder placed at the side of the locomotive and attached to the frame just below the fireman's seat-box. The connection between this operating steam cylinder and stoker is by means of a cross shaft with the necessary arms and connections to give the conveyor and elevating mechanism the reciprocating action required by this particular design of forwarding means.

The individual characteristics of this particular stoker are *the firing of the coal over the fuel bed in separate charges*, representing very nearly the general scheme of hand firing and *the necessary intermittent action needed to permit each charge of fuel to be consumed before another is placed in the same location in the firebox.*

This stoker is firing a locomotive successfully, but has not been in service long enough to warrant any conclusions as to its commercial possibilities, only one of them having been put into service to date.



General view of Standard stoker.

This is a general view of the Standard stoker showing arrangement of conveyor, jets, and grates. This stoker is also of the overfeed scatter type, but it has the peculiarity of firing the locomotive by putting the coal into the firebox by conveying it to a point just below the back section of the grate area and elevating it by a vertical screw placed in a firing pot in the middle of the back part of the firebox. The distribution of the coal over the grate area is by steam jets, the nozzles for which are placed so as to come in the midst of the body of coal just as it reaches the top of the vertical screw, and the distribution is secured by having the jets pointed toward different parts of the grate area. There are no movable or stationary mechanical directing means to assist the steam jets in distributing the coal as with other stokers.

This stoker is one of those designed to supply fuel at a continuous rate over the entire grate area as compared with the intermittent action of the Gee stoker, which fires the coal in separate charges, as just described.

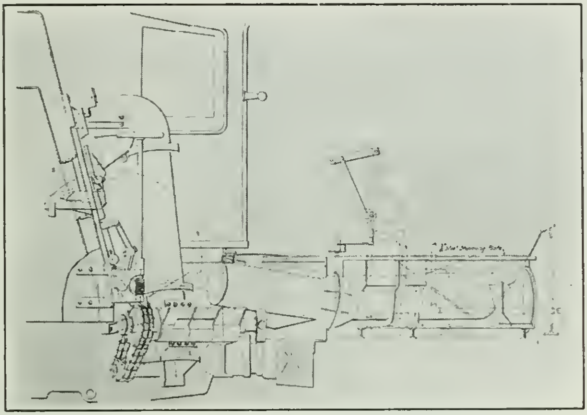
The Standard stoker also has arrangements for crushing or preparing the coal, this being accomplished by the use of a crushing zone at the forward end of the heavy cast-steel helicoid screw shown in the left-hand section of this general view. The necessary flexibility for the movement between locomotive and tender is secured by the ball joint actions, also plainly shown in the view.

The power motor which operates this stoker is a small, high-speed steam turbine on the left-hand side of the locomotive, and connection is made to the stoker through a train of gears with suitable reversing mechanism required for the clearing of the stoker from foreign matter or clogs of any description.

Suitable arrangements are provided for adjusting the jets to different degrees of force and also to shut one or more of them off when it is desired to stop the forcing of coal to any given part of the firebox. The general action of the jets is intermittent, being controlled by an operating valve moved mechanically by the arm and rod connection shown.

It might occur to you that the action of the jets being intermittent would result in firing separate charges of fuel to the grate area. This, however, is not actually the case, as the action of the jets is graduated so that the building up of the blast to maximum and decreasing in force to the minimum serves the purpose of waving the coal over the grate area by the use of the increasing and diminishing forces of the jets, and the valve controlling the jets begins to open almost immediately after each jet action, so that the result is a spreading of the coal continuously rather than firing it in separate charges.

Some fifteen or sixteen of these stokers have been applied to locomotives to date, and are firing the locomotives successfully.

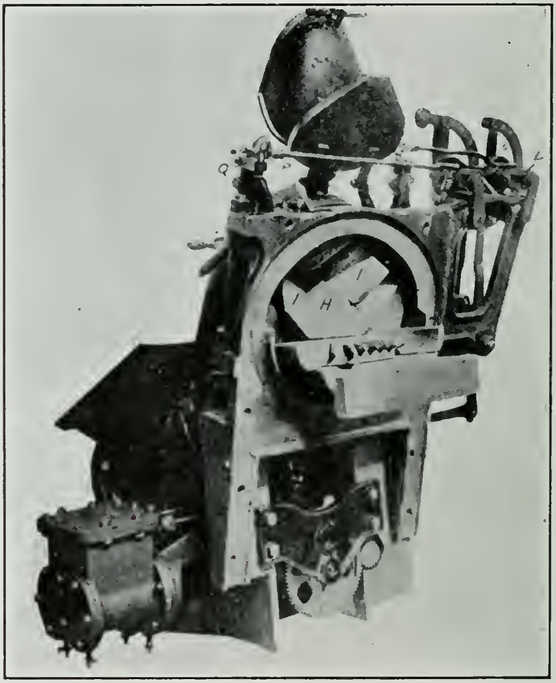


Drawing showing arrangement of Hanna stoker.

This is a drawing showing the general arrangement of the Hanna overfeed scatter type locomotive stoker. The peculiar characteristic of this stoker is the use of a combination of *movable mechanical directing means and continuously operating steam jets* for distributing the coal over the grate area. It also has means for crushing the coal preparatory to forwarding it to the elevating and firing means.

The driving motor is a twin-cylinder, double-acting steam engine placed on the locomotive tender, usually in one of the forward ends of the water space. The operating routine is to have the coal passed to the crusher through the opening in the deck of tender, and after being crushed the coal is forwarded by a cast-steel helicoid screw to a receptacle at the base of the elevating means, which is another cast-steel screw placed in the vertical casing just at the left of the ordinary fire door of a locomotive. At the top of the elevating means is a large elbow, or goose-neck, through which the coal is forced by the pressure of the vertical elevating screw and finally falls by gravity over the directing vanes, or wings, to the firing plate placed inside of the regular firing door of the locomotive.

This photographic view shows the firing plate, above which will be noted the main nozzles of the firing jets placed in fan-shaped arrangement, and above these jets will be seen the ridge plate and movable mechanical means or directing wings, which serve to assist the jets in distributing the coal over the grate area.

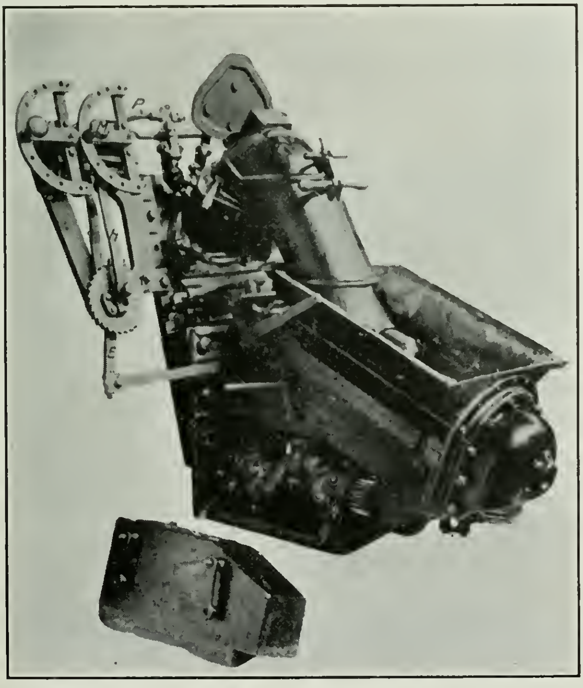


Photograph showing views of firing plate, steam jet nozzles, and stoking mechanism of the Hanna stoker.

Just below the main jets is a long slot in the casting at the level of the firing plate, and this can just be seen in the view.

The operation of the mechanism shown in this view is about as follows: The coal reaches the vanes at the upper part of the opening, coming by gravity from the goose-neck, and these vanes are in turn operated by the levers placed on backhead of locomotive, which will be shown in the next view, these levers keeping the vanes in constant motion while the stoker is in operation, which results in the coal being poured down over the jets, and the stream of coal is gradually directed from side to side, so that the jets pointed in any given direction intermittently force part of the coal, as it is directed over them, to some portion of the grate area; these jets being arranged in the segment of a circle, and the passing of the coal gradually from side to side in front of them has the effect of waving the coal over the grate area from one side of the firebox to the other. Steam also is forced against the coal through the long slot just below the main jets, but at a lower pressure, and this serves to force part of the coal just over the firing plate to the back of the grate area.

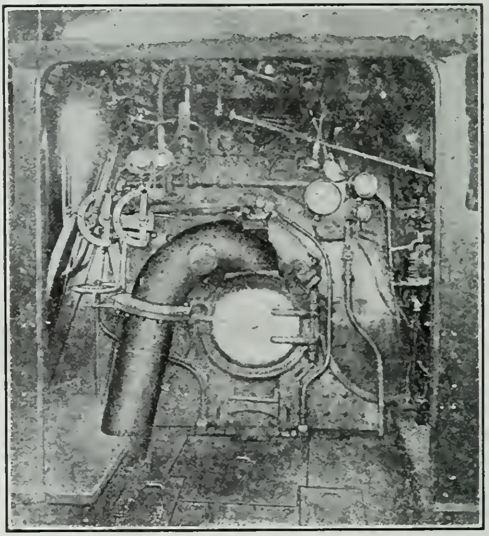
This delivery of the coal to one side of the firebox for a short time and the similar delivery in turn to the other side would make it proper to classify this stoker with those of the intermittent firing type, as a charge or " fire " is, in a partial sense at least, delivered to the different sides of the firebox and allowed to burn until the cycle of mechanical movement brings another delivery of fuel. The jets are constantly in action, the mechanical direct-



Photograph showing the adjustment levers for control of distributing wings of Hanna stoker ing means are also continually in motion, but the delivery of the fuel is intermittent—an arrangement just opposite from that of most stokers of the overfeed type.

The fan-shaped arrangement of main jets serves also as a fork, or set of fingers, to partially separate the coarser lumps of coal from the fine slack, which latter drops to the firing plate and is forced to the grate area by the low-pressure steam emitted from the long slot just mentioned; the larger particles are more violently forced by the steam jets to other parts of the grate area.

This is a photograph of one of the earlier forms of the Hanna stoker, but will serve in this connection to show the arrangement of control levers which operate the movable mechanical means which assist the steam jets in distributing the coal as just described, this lever arrangement being the same in the present installations of this stoker as shown in this view. The hopper shown was the receptacle into which the coal was shovelled manually. The moving of the small levers on the quadrants here shown has the effect of changing the range of movement of the directing wings so that the coal may be kept directed toward a limited part of the grate area, or by moving these levers on the

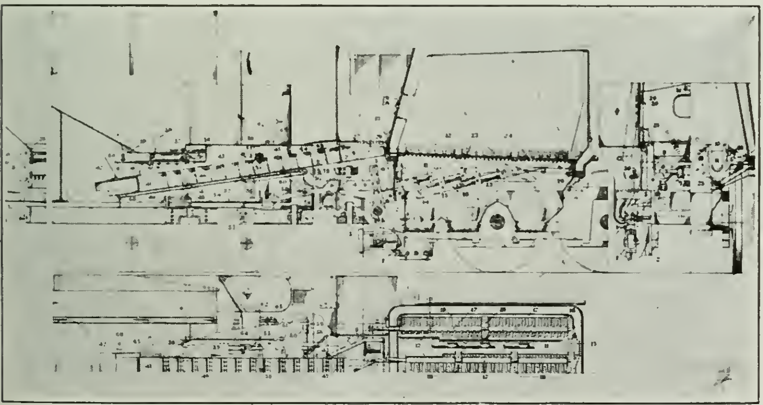


Photograph of backhead of locomotive showing Hanna stoker device lowered for hand firing.

quadrants the range may be changed so that the movement is over the entire grate area.

It will readily be appreciated that as this stoker is applied to the ordinary fire door of a locomotive it is essential that some means should be furnished for getting the stoking mechanism out of the way in the event of failure, or for the purpose of building the fire at the round-house by hand, and this view shows the upper part of the elevating means and the goose-neck, but the main stoking mechanism has been lowered below the deck of the locomotive cab. At the left of the goose-neck will also be seen the quadrants and operating levers shown in the other view.

Approximately forty of these stokers have been applied to locomotives to date, about twenty of which of the latest design are in daily service and firing locomotives successfully. About twenty of the earlier forms of this stoker, with which the fireman was required to shovel the coal into the hopper below the elevating means of the stoker proper, were applied to locomotives, but found to be either not practical or of sufficient advantage to warrant their continued use. Those at present in service, however, are giving good satisfaction.



Drawing showing general arrangement of Crawford underfeed stoker.

This is a drawing showing the general arrangement of the Crawford mechanical underfeed stoker as in use on a large number of Consolidation and Pacific type locomotives on the Pennsylvania Lines West.

This stoker was designed and developed by Mr. D. F. Crawford, General Superintendent Motive Power, Pennsylvania Lines West, and, as it was one of the first stokers to be applied to locomotives other than in an experimental way, it is of special interest in connection with the subject of the evening.

As explained earlier in this paper, the different stokers which have been developed have each individual characteristics as to mechanical design and method of handling the fire. This stoker is the foremost representative of the underfeed principle of firing; it has been in continual operation for the past four or five years, and well illustrates what can be done in the matter of successfully firing locomotives in that way.

The Crawford stoker is designed on the theory that the use, more or less completely, of the coking or gas producer process, during the progress of combustion, contributes toward economy and reduces the amount of black smoke usually made by a locomotive when working at or near its maximum output, and to secure this coking of the coal the fuel must be supplied to the fire from the bottom upwardly, hence the term underfeed stoker.

The mechanical arrangements of this stoker include preparatory means, or crusher, at or near the back part of the reciprocating forwarding means, which are shown on the forward part of the locomotive tender in this illustration. The forwarding means are placed generally horizontal, being only raised sufficiently at the front to elevate the coal over the top of the receiving hopper, in the bottom of which the main feed plungers operate. The crushing mechanism also serves the purpose of a measuring and feeding device to prevent the overloading of the conveyor. It is timed in operation with the reciprocating forwarding means, and only permits a sufficient amount of coal to enter the back part of the conveyor as can be readily and without congestion carried forward in the normal operation thereof.

The conveyor is made up of sets of fingers carried on a frame and hung from above the top of the trough; this frame is reciprocated forward and backward with considerable travel, so that the vanes or fingers, the bottom ends of which just clear the bottom of trough, serve to carry the coal forward and in the return stroke are lifted over the top of the coal which has just been moved toward the front end of the conveyor trough, and some of them in each set drop behind the coal below them, and in turn carry some more coal forward.

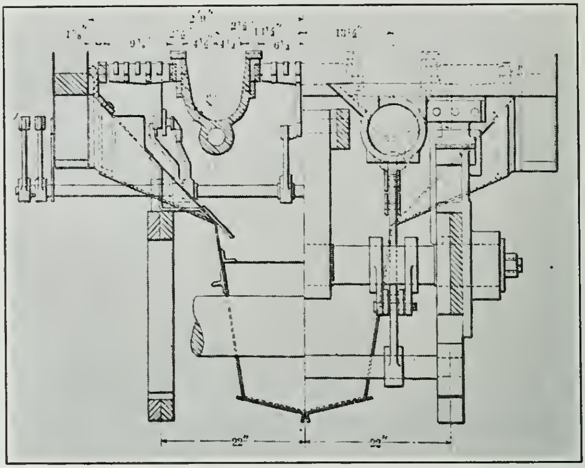
The purpose of making these vanes in sets of fingers is to prevent a lump of coal keeping the whole vane raised up, which would then move forward without carrying the coal with it, but by cutting the vanes up into several sections, or fingers it is found in practice that some of them will drop back of the coal in that section of the trough, and thus a general carrying forward of the coal is secured.

The action of the crushing, or feeding mechanism placed just below the opening in the coal pit of tender is timed in relation to the reciprocating movement of the conveyor, and is connected by substantial mechanical means to the operating steam cylinder on the locomotive, so that its action is powerful enough to crush any large lumps of coal which may drop into the crushing area in front of the piston and be broken up in the operation of being pushed through the feed opening into the back part of the conveyor, the lumps then being small enough to be readily taken up by the vanes or sets of fingers in the conveyor, as shown in this drawing, and forwarded, as just described.

The coal, on reaching the forward end of the conveyor, drops into a hopper in the bottom of which are the main feed plungers, which operate in a substantial casting placed just under the back-head of locomotive boiler.

In the firebox are placed two heavy cast-steel fuel troughs, into the back part of which the feed plungers force the coal. At points spaced throughout the bottom of the fuel troughs are auxiliary plungers which serve to assist in forwarding the coal still farther forward. Small castings in the shape of fingers or teeth are placed adjacent to the outward end of the auxiliary pistons to assist in enlarging the end thereof, and serve as agitators to keep the coal moving forward in the feed troughs as the auxiliary plungers are operated.

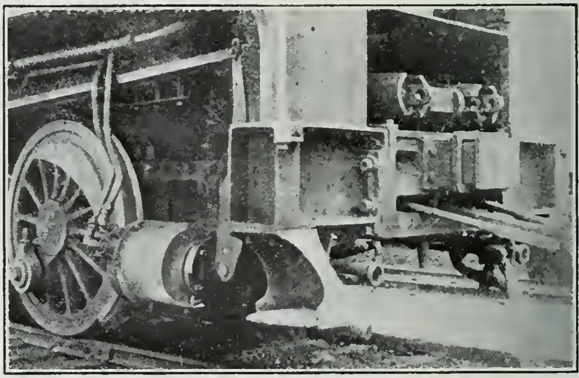
The grates of the firebox, of special form, are placed between the troughs and also between the extreme right and left troughs and the sides of firebox, and may be either level or at an angle of something like 42 degrees to represent the normal angle of the coal at rest as it is forced over the sides of the troughs by the feed and auxiliary plungers.



Section showing shape and size of main feed trough of the Crawford stoker.

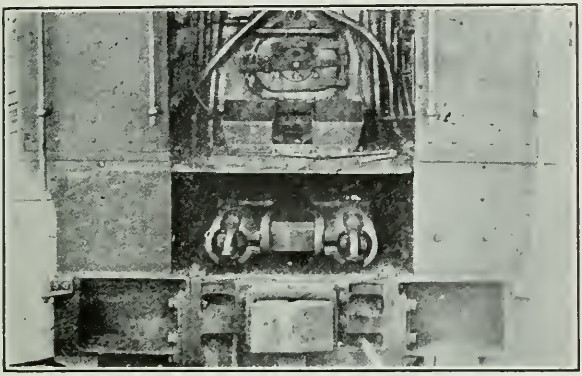
This view will show the troughs more in detail and the grates at each side. In this drawing the grates are of the level form.

The Crawford stoker is operated by means of a steam cylinder attached to back end of locomotive frame on left side of locomotive, and is connected to the stoker mechanism through means of cross shaft with arms thereon to attach to the steam cylinder, the conveyor, the crushing mechanism, and the main and auxiliary feed plungers.



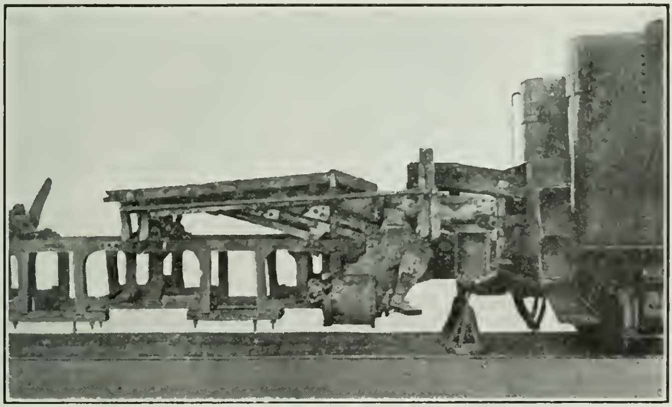
Photograph showing operating cylinder of Crawford stoker attached to locomotive frame.

This photograph shows the main operating cylinder of the Crawford stoker and the back part of main feed plungers.



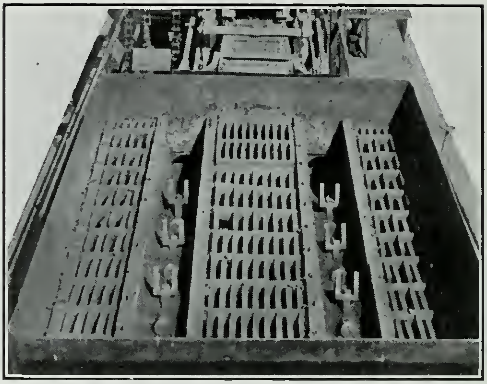
Photograph showing main feed plungers, Crawford stoker.

This photograph shows the back part of main feed plungers of the Crawford stoker and, rather indistinctly, the upper part of coal hopper in which the plungers operate.



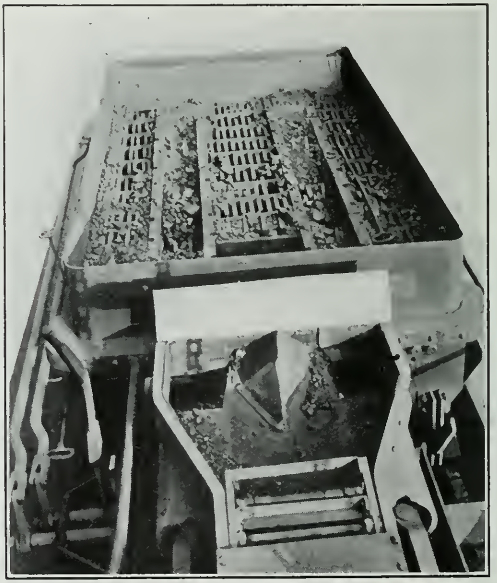
Photograph of general arrangement of Crawford stoking mechanism.

This photograph, while not very clear in its details, will serve to show the general arrangement of the stoking mechanism of the Crawford stoker and the forward end of the conveyor just above the feed hopper. The operating cylinder and lever attachment to cross shaft can also readily be observed.



Photograph of general plan of Crawford stoker, showing trough and grate arrangement.

These photographs will perhaps serve to give a better idea of the general arrangement, grates and stoking troughs of the Crawford stoker.



Photograph of general plan view of Crawford stoker, showing troughs, agitators, and main feed hopper.

The agitators on auxiliary plungers can be seen in this view and also the main feed hopper and feed piston positions.

The method of firing is about as follows:

The reciprocating action of the crushing and conveying means brings the coal to the main feed hopper, and it is directed toward each feed piston by a ridge plate therein. Each main feed piston forces its portion of these charges into the back part of the main feed troughs in the firebox through openings in the casting underneath the mud ring.

In this operation any lumps of coal which are larger than these openings will, of course, be additionally broken up by a similar action to that of the main crushing and measuring piston. These charges of fuel, forced into the trough in this way, serve as forcing means to push the coal, already in the troughs, still farther along, where it is taken up by the auxiliary feed pistons, and at the same time some of it is forced over the sides of the troughs as it travels toward the forward part of the firebox. The troughs are usually made with slight offsets in their widths which serve as abutments or partitions, similar to those described in the Barnum stoker, and these partially assist in lifting the coal up out of the troughs to the grate area. The forward end bottoms of the troughs are inclined upward, so that the small amount of coal which reaches the vicinity of the throat sheet is in turn lifted out of the trough on to the grate area in the front part of the firebox.

In firing a locomotive with this stoker, the fire is initially made in the round-house by hand firing in the ordinary manner. The stoker is usually not put into operation at all until the locomotive begins to do actual work in hauling the train.

The coking process is secured in the operation of this stoker by the filling of the feed troughs and supplying of sufficient coal to the grate area at each side thereof to make it possible for the fire to be maintained at a proper point without the stoker being operated continually.

The stoker is operated possibly ten strokes or so at a time; that is to say, a " fire " is put in and allowed to be undisturbed for a suitable period to permit the coking to occur.

During the time the fire is undisturbed by the operation of the main and auxiliary feed pistons of the stoker the green coal on the top of the feed troughs becomes ignited from the heat of the fire on the grates, and the fire is then well ignited over the entire firebox area. A casual observation of the fire at this time would not disclose the feed troughs at all. As no air is admitted up to the fire through these feed troughs, the ignited coal, on top of the troughs, together with the general heat of the firebox, serves to distil and break up the volatile matter, the hydrocarbons, from the next lower stratum of coal in the troughs. If the operation of the stoker is timed properly this stratum of coal becomes coke, and the next operation of the main feed and auxiliary plungers serves to force more green coal along the troughs, which in turn lifts the coked coal and turns it over on to the grate area.

Without going into the theory of combustion, it might be well to state that this gas-producing effect of the coking process undoubtedly contributes toward economy by breaking up these hydrocarbon contents very early in their travel as they pass through the ignited stratum as explained; the hydrogen combining with oxygen earlier than it might otherwise have done, and the carbon, requiring more time or raising to proper temperature, also starts to combine with oxygen nearer the fire-bed than with hand firing.

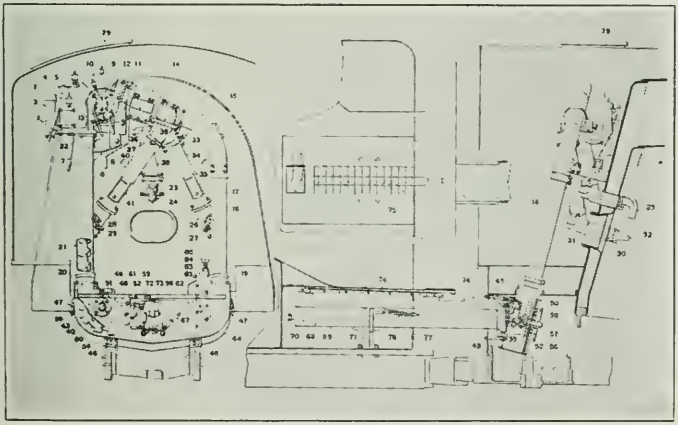
It will readily be observed that in order to secure this coking process there must be a proper time element introduced at intervals in the operation of the stoking mechanism, and the regularity of these intervals and the length of time the fire is at rest has much to do with the perfection of operation when firing a locomotive, or stationary boiler, for that matter, in this manner. If the demand upon the locomotive is such that the stoker pistons must be kept moving rapidly to supply a sufficient amount of coal to keep the engine hot, then, of course, the coking process is disturbed, more smoke is made, and probably less economy secured.

Any one who has observed the operation of firing a locomotive with this stoker in actual service will admit at once that this is a very excellent way of accomplishing the desired result, and it is no wonder, therefore, that this method has its earnest adherents.

There are nearly four hundred of these stokers in actual service, certain divisions of Pennsylvania Lines West being completely equipped, and they have been in service for the past three or four years with such success that this stoker may be considered very properly as one of the possibilities for general application.

Having thus described the underfeed stoker which has so successfully demonstrated the correctness of the theory of that method of firing a locomotive, you will no doubt be interested in the next description, which is that of the Street locomotive stoker, of which some six hundred are now in service on very large modern locomotives. It may very properly be considered as the principal representative of another method of firing; namely, that of supplying coal to the entire surface of the fire continuously at *the rate of combustion*, no coking periods being provided for as in the method just described.

The modern locomotive is called upon to operate at widely varying rates of horse-power output, often from maximum to zero within very short spaces of time, and this method of firing is based on the theory that there should be a given rate of combustion per square foot of grate area at any given time just sufficient to supply the steam output required of the locomotive boiler at that time; that is to say, there should be the same flexible control of the fire that there is of the throttle and cut-off.



Drawing showing general plan of Street locomotive stoker.

This drawing will give you an idea of the general arrangement of the Street locomotive stoker, which consists of a conveying, elevating, and stoking mechanism.

This stoker is designed to handle only coal which will pass through a screen having openings not to exceed three inches square. A screen of this character is placed just below the bottom of coal pit of locomotive tender, and above this screen are placed movable slides, so that a portion only of the screen is exposed at one time. Below the screen is placed a conveyor trough in which is operated the forwarding screw of helicoid form, which serves to carry the coal forward to the receiving hopper which constitutes the bottom part of the elevating mechanism.

In the left-hand section of the drawing is shown the general elevating and driving mechanism of the stoker. The endless chain of elevator buckets is driven by a single-acting, high-speed engine built into the upper left-hand part of the elevator, as will be plainly noted on the drawing. This high-speed engine drives the endless conveyor through means of worm, worm wheel, and the usual arrangements of sprocket wheels placed at different points. No sprocket is placed at the upper right-hand section of the elevator casing, however, as it is necessary to drop this part of the casing to clear the locomotive throttle connections which are at this point on backhead of locomotive.

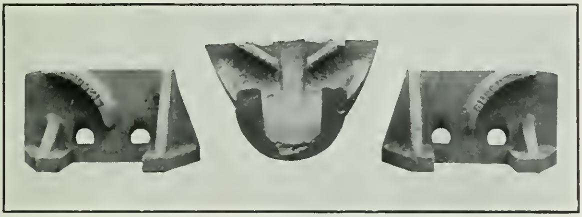
In the centre of upper section of elevator casing is placed the mechanism which apportions the coal to the different firing points by first screening out the smaller particles and directing them toward the middle firing means, as will be later described, and then equally, or unequally, as may be desired, dividing the coarser particles of coal and directing them toward the side distributers.

On the right-hand side of the drawing will be seen a cross-section of the backhead of locomotive giving a better view of the hopper at bottom of elevator and showing the downwardly directive feature of the centre distributer; the purpose of this being to assist in directing the finer particles of coal or dust to a zone in the back part of the firebox, where these small particles will be less apt to be taken up by the draft and carried away before they can be properly consumed.

One of the side distributers will also be observed which serves to direct the coal generally forward, and on the bottom of which are placed directing ribs which assist in spreading the coal over a fan-shaped zone on each side of firebox. Each of the side distributers directing the coal over a fan-shaped zone in this way serves to cover the main part of the grate area, overlapping slightly in the centre of the firebox, leaving a small, triangular area at back of grate, which is covered by the finer coal directed there by the centre distributer as just mentioned.

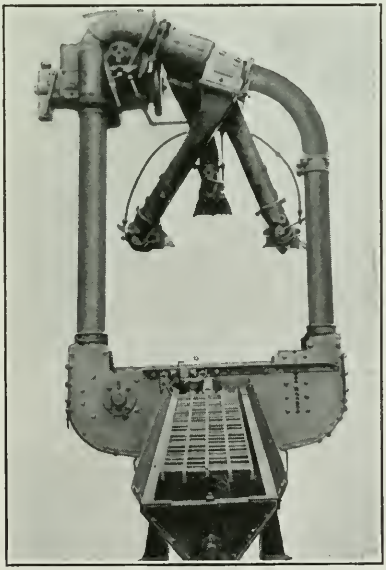
The distributers at the side and centre are simply rough castings removable from the ends of the tubes which are placed in openings through backhead of locomotive boiler, and which permit their replacement when warped or destroyed by heat of firebox after their normal period of service.

At the point of connection between the delivery tubes and the distributers are placed elbows, and through the backhead are the removable tubes to which the distributers are attached on inside of firebox. In the elbows are placed firing nozzles, to which are made steam connections from the blast device, the latter operated by the stoker motor.



Photograph showing directive rib on stationary distributers—Street stoker.

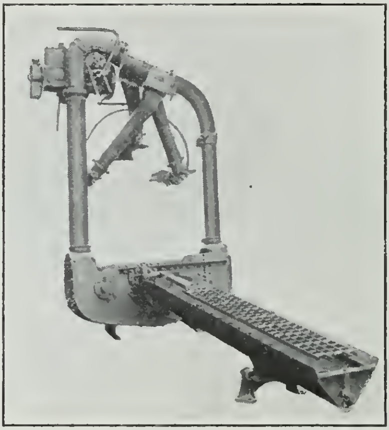
This photograph will give you a better idea of the directive ribs placed upon the lower part of the centre and side distributers for the purpose of assisting the blast device in distributing coal over the grate area to the different zones described.



Photograph of end view of assembled Street locomotive stoker.

This photograph of end view of Street stoker, assembled for exhibition purposes, will give you a better idea of the general arrangement, the view being directly toward the backhead of boiler.

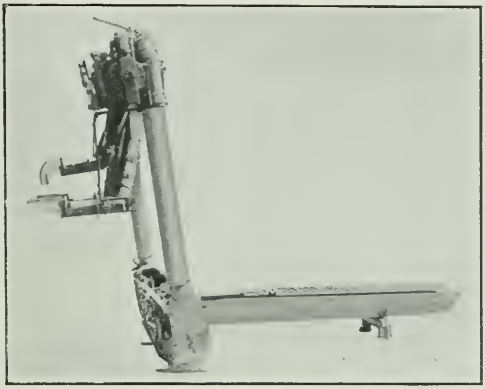
This view will assist in showing the relation of the parts, especially the coal screen above the conveyor trough and the slidable connection of the conveyor trough on the tender. The whole stoker being attached to the locomotive proper, the necessary flexibility between locomotive and tender is provided for by swivel connection at forward end of the conveyor trough at the point where it is attached to the elevator hopper, and the fore-and-aft movement incident to the usually loose coupling connection between locomotive and tender is provided for by simply having the conveyor trough slide upon the bracket placed below the trough, as can be readily observed in this photograph.



Photograph of quartering view of Street locomotive stoker.

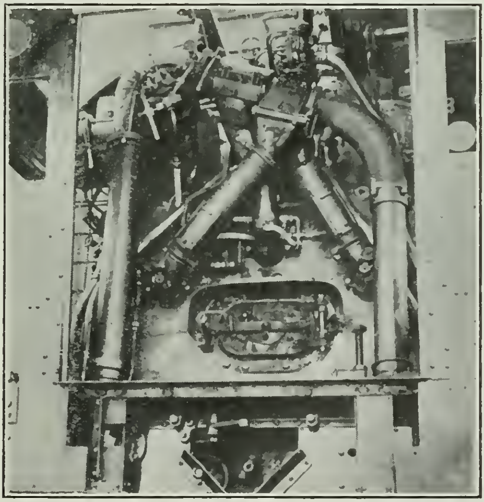
This photograph of the general side view of the stoker will give you a better idea of the driving means for operating the conveyor screw through sprocket connections on back of hopper, which are in turn operated by the endless elevator chain of buckets as they pass the main sprocket in lower left-hand part of elevator hopper, and also the elbows, tubes, and distributers which are placed on and through the backhead of the locomotive.

This view, showing the actual installation on a Mikado locomotive, will serve to show the general arrangements of an installation, and particularly the ordinary fire door, which is left available for such observation of the fire as is necessary, or hand firing to build the fire initially in the round-house and care for



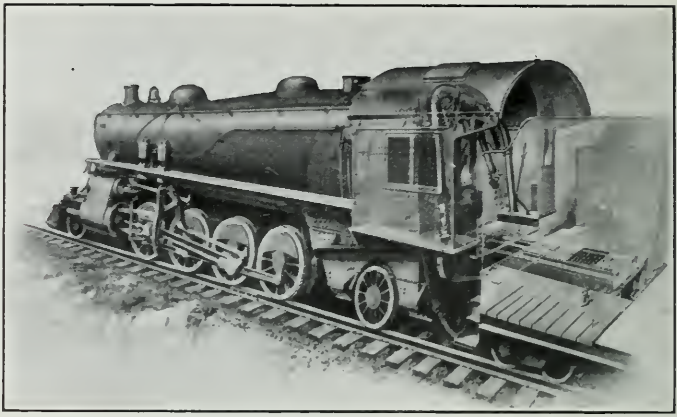
Photograph of general side view of Street locomotive stoker.

the fire when the locomotive is standing by at terminals or on sidings.



Photograph of view into locomotive cab of Mikado locomotive equipped with Street stoker.

This is a photograph of a pen-and-ink sketch of a large Mikado locomotive equipped with the Street stoker, and will serve to give a better conception of the general arrangement of the openings above coal screen and the availability of the ordinary fire door and the usual space in cab for locomotive engineer and fireman. This view also shows a sliding door provided in roof of cab for inspection of stoker motor.



Photograph of phantom view of Street locomotive stoker.

As I mentioned earlier in the paper, this stoker is particularly representative of that method of firing by which the coal is put into the firebox above the level of the fuel bed and dropped upon the surface of the fire continually, while the locomotive is being operated, and distributed over the entire grate area at the rate of combustion. Other stokers have been designed to partially carry out this method—the Hanna stoker, for instance, while putting coal into the firebox continually, does not spread it over the entire grate area at the rate of combustion, as it will have been observed that the movable mechanical directive means which assist the jets in the Hanna stoker in distributing the coal have the effect of putting coal to the different parts of the firebox in excess of the rate of combustion and then moving the directed stream of coal toward other parts of the firebox to permit the coal, just delivered, to be consumed in the meantime.

The routine of the process of firing a locomotive with the Street stoker is about as follows: The coal is assisted in passing down through the slide opening just in front of the main body of coal in the locomotive tender by the movement of the tender screen, this screen, by the way, being operated through a travel of three or four inches fore and aft by mechanical means and connections in the main elevator hopper. This movement of the screen materially assists a stream of coal being regularly delivered to the conveyor trough just below the opening, where it is carried forward and dropped into the main elevator hopper.

The endless chain of buckets, each bucket lifting about one pound of coal, then takes up the coal and carries it to the main discharge pipe in upper section of elevator casing, where it is again screened, divided, and directed toward the firing elbows. The coal drops by gravity to these elbows and is forced into the firebox by steam jets which are controlled by the blast-controlling device operated by main driving shaft of the elevating mechanism. The cams on this blast device are within the control of the fireman, so that the interval and duration of the jets may be adjusted to meet the conditions of operation. The jets are intermittent in action, but the coal is admitted to the firebox continually and is, in effect, scattered over the entire grate area all of the time while the stoker is in operation.

During the slight interval between the operation of the jets the coal is carried into the firebox from the firing elbows by the draft of air which enters the firebox at the stoker openings and is carried partially over the grate area, and, as the jets start, the coal is still further driven forward and, as the pressure of the jet increases, the wave of coal is projected farther and farther toward the throat sheet. As the pressure begins to die down the main wave of coal is then spread, with less force, toward the back part of the grate area.

The distributers, or stationary mechanical directing means, are placed above, rather than below, the tube openings just inside of the firebox, and on the bottom part of these distributers are the directing ribs which you have seen. The main purpose in placing these distributers above the openings is to direct the coal downwardly rather than forward. The steam jets, acting as plungers, force the coal forward, but at the same time the expansion of the steam as it leaves the nozzles would lift the smaller particles of coal to the upper part of the firebox and some of it might be carried on over the arch and through the tubes without being consumed. The distributers serve the double purpose, therefore, of keeping the coal downwardly directed toward the grate area and at the same time materially assist in spreading it.

The motor which operates the stoker has a variable speed governor—variable speed in the sense that it can be set to run at different rates of speed as may be required to drive the conveying, elevating, and stoking mechanisms at speeds suitable for supplying coal in proportion to the amount required for any given output of the locomotive.

The several constant speeds of the stoker motor make it possible for the fireman to set the stoker to run at the different rates for any interval of time that the locomotive may be operated with any particular setting of the reverse lever and throttle. The highest speed of the stoker motor represents the delivery of the proper amount of coal to fire the locomotive to its maximum capacity, and at the lower speeds at which the motor can be set the delivery of the coal will be in amounts proportioned properly to operate the locomotive at several different rates of output. The relation between the delivery of the coal by the conveyor and its elevation by the buckets of the elevator is arranged for in the initial application of the stoker to any particular locomotive.

If a delivery of coal is required of less quantity than the delivery at the slowest speed of the motor, the amount can be further reduced by partly closing, with the sliding plate, the opening over the tender screen or by disconnecting the stoker motor from the stoking mechanism through means of the friction clutch which is introduced between the motor and the stoker for the purpose of readily stopping and starting the stoker when desired.

Means are also provided to permit the fireman to control the supply of coal delivered to each of the three elbows. The increase and decrease of the supply to the centre elbow are adjusted by turning larger or smaller screen openings to register with the discharge opening for the middle distributer, so that in this way more or less of the fine coal is taken out of the main stream of coal as it passes over the upper screen.

The supply to each of the side elbows is regulated by a dividing rib which can be placed at different points in the opening so that the flowing stream of coal will be divided up in different proportions between the tubes going to the side elbows.

While there are means supplied, as described, for making different adjustments of regulation of the speed, as well as the dividing means for supplying the coal to the different zones in the firebox, the adjustable features generally of this stoker are designed with the idea of permitting a definite setting to be determined, and then permitting the stoker to operate at that setting of speed or coal delivery, so that, so long as the locomotive is worked at the point requiring that particular amount or distribution of the coal, the stoker will need no additional attention on the part of the fireman other than to see that the coal is being fed properly to the opening above the screen in the tender.

In designing the Street stoker the firing problem of itself was considered as of first importance; that is to say, the keeping of the fire in direct relation to all of the conditions of operation of a modern locomotive, especially that of securing the absolute maximum output and satisfactorily caring for the abrupt changes required of the power plant, yet it can be said that the general scheme of firing is in line with the best recommended practice and must contribute toward economy, although in a different manner from that of the underfeed method, and at the same time make it possible to burn fuel that could not be used for hand firing.

I beg leave to quote in this connection a few paragraphs from Technical Paper No. 80, issued by the Department of the Interior, Bureau of Mines, which particularly commends this method of firing, especially as to its possibilities for successfully burning slack coal:

"Soft or bituminous coal should be fired in small quantities at short intervals, the quantity that should be fired varying with the size of the grate and the intensity of the draft.

"Small and frequent firing makes the coal supply more nearly proportional to the air supply, which in most hand-fired furnaces is nearly constant. They also reduce the formation of crust on the fires and the chance of holes in the fuel bed. With small and frequent firings better combustion is obtained.

"When a fresh charge of bituminous coal is spread over an incandescent fuel bed, the coal is heated rapidly and twenty to forty per cent. of the combustible matter is distilled off in the form of gases and tar vapors. This distilled combustible matter requires for its combustion additional air. It can be readily understood that the heavier the charges, the larger amount of volatile combustible driven off two to five minutes after firing.

"To burn the volatile combustible, about fifteen times its weight of air needs to be supplied. Therefore, immediately after firing, a large quantity of air should be admitted over the fire, and this quantity should be gradually reduced as the distillation of the volatile combustible nears completion. The larger the quantity of fresh coal fired at a time, the larger the volume of air needed for the complete combustion of the volatile matter.

"*An ideal case is the one in which the coal is fed into the furnace constantly and at a uniform rate, as is done with some mechanical stokers.* The coal supply is then as uniform as the air supply.

"Small and frequent firings reduce the tendency of many coals to fuse and form a hard crust at the surface of the fuel bed. Most of the soft coals used for steaming purposes fuse in this way, and the crust in places prevents the free passage of air through the fuel bed. In these places the fuel burns slowly. At other places in the fuel bed where the crust has not formed or where it is cracked, a large quantity of air flows through and the coal burns quickly. On account of this uneven flow of air through the fuel bed the coal burns unevenly, and as a result the rate of combustion and the capacity of the boiler may be decidedly reduced. Such fusion of coal is particularly troublesome in case the coal contains a large percentage of slack and where large quantities of it are fired at a time, for then the crust must be broken and the fuel bed levelled frequently. In an extreme case this crust must be broken and levelling done after each firing. If, however, a little coal is thrown each time on the hot fuel bed, the thin layer of fresh coal burns through before a hard, tight crust can form. Often a coal gives trouble from the formation of crust when fired in large quantities and yet burns comparatively freely (without fusing into crust) when fired in small quantities, so that a good fire can be run two or three hours without the use of a rake. Therefore, to avoid or to reduce the formation of hard crust at the top of the fuel bed, the fresh coal should be fired in small quantities so that it will make a thin layer that will not fuse and interfere with the flow of air. If the flow of air is not hindered, the layer of fresh coal will burn through without fusing into crust. As this thin layer of fresh coal burns through in a short time, the small firings must be made at short intervals.

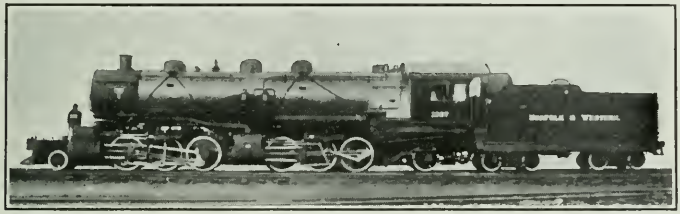
"With frequent firings there is much less danger of holes forming in the fuel bed. The thin spots are seen and covered with fresh coal before the holes actually form. In this way frequent firing reduces the losses from excess of air."

Slack was never used extensively for locomotive fuel until the advent of the Street stoker, and now something over 600 locomotives are being fired with coal that will pass through a screen having two-and-a-half or three-inch round holes.

If, by chance, a hand-fired locomotive should get a tank of this kind of fuel, the fireman would usually complain of "bad coal."

With the main points of the stoker story in our minds, as related thus far,—that is, the aims of the different inventors in the early state of the art, the findings of the stoker committees to the effect that not much of real value had been accomplished up to the end of the year 1911, and the descriptions given of the machines sold commercially since that time and now in service, —some information about the principal stoker-fired locomotives will be the best way of illustrating the progress made in the last three years.

In connection with the description of the locomotives, I shall also try to give information about the work the stokers are doing which will enable you to judge of their present economic value and draw conclusions as to the possibilities for the future.



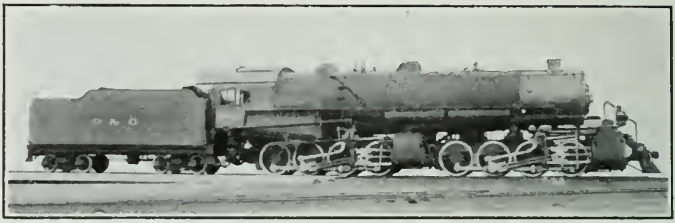
Photograph of Norfolk and Western Z-1 Mallet road locomotive.

This is a photograph of a Norfolk and Western Z-1 and Z-1-A road Mallet locomotive having 72,800 pounds tractive effort and 62.2 square feet grate area. Not a remarkably large locomotive, but well within what we have come to term the stoker class. There are 120 of them in service, all stoker-fired, and, from the stoker point of view, these locomotives are of somewhat unusual interest. They were practically the first locomotives to be bought new with mechanical stokers in the original specifications and the first ones to be commercially equipped. Forty of them were ordered to be furnished by the builders, complete with stokers, during the summer of 1912; forty during the summer of 1913, and forty during 1914. Of the 120, 105 have the Street stoker and 15 the Hanna.

Each of these locomotives hauls from one and one-half times to twice the tonnage of the consolidation locomotives displaced by them.

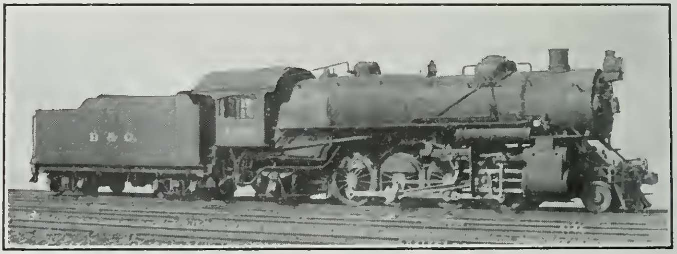
The fuel used is mine screenings or slack secured from the mines direct or screened by the railroad company from the coal used for hand-firing. Practically none of it could be used for hand-firing.

This locomotive was also built to be stoker-fired, is much larger than the one just shown, and, if size alone has anything to do with the need for mechanical stokers, this would be a shining example. The tractive power is 105,000 pounds and grate area 99.9 square feet. Thirty of this class are in pusher service on the Baltimore and Ohio, all having Street stokers.


Photograph of Baltimore and Ohio Mallet pusher.

The fuel used is mine screenings secured by passing run-of-mine coal over bar screens with bars placed one and five-eighths inches apart. Some of the thirty have been in service three years and all of them over eighteen months.

Using 100 pounds of coal per square foot of grate area per hour as a conservative figure for the amount of good quality coal required to fire these locomotives to their rated capacity, it will be admitted at once that this, then, would be a place for stokers, even if there were no other considerations.

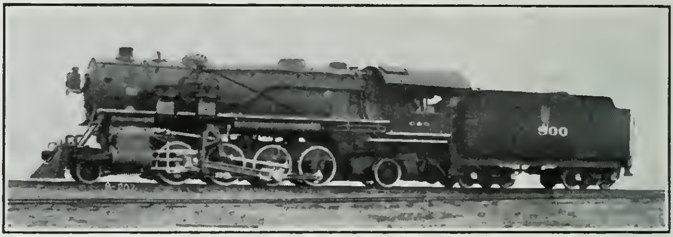

Photograph of Baltimore and Ohio Mikado.

This locomotive represents another phase of the stoker proposition. The locomotives just shown are unquestionably of the stoker class from their size alone, requiring more coal to fire them to their maximum capacity than could be put in manually, especially for any extended period. This locomotive has but 54,000 pounds tractive effort and 70 square feet of grate area, and can be fired by hand very satisfactorily in regular service. There are 320 of these locomotives on the Baltimore and Ohio, 160 of them stoker-fired with the Street stoker, 160 hand-fired. There are both saturated and superheated engines stoker- and hand-fired, so that ready comparisons can be made of the advantages, if any, of the use of the stoker on an engine of this size under various conditions of operation. Fifty of the stokers were applied during the summer of 1912, and the other 110 during the year 1913, so that all of the stokers have been in service long enough to permit these comparisons. There are two things which have been accomplished on the 160 stoker-fired engines which are of interest.

First, each locomotive stoker-fired is given more tonnage per train as its rating than the same engine hand-fired, and this increase in tonnage can be safely stated to be 500 tons for a superheated stoker-fired engine over a superheated hand-fired, and at least the same amount for a saturated stoker-fired over a saturated hand-fired, and this work is done on a stoker-fired locomotive with fuel that could not successfully be used for hand-firing in regular service. This fuel is secured by screening run-of-mine coal over bar screens with the bars one and five-eighths inches apart, or is purchased direct from the mines, this latter being the case when gas coal mine screenings are used.

A careful record kept for a considerable period of the hand-firing done on stoker-fired engines showed that at least 90 per cent. of the total fuel was fired with the stoker, counting everything, and in many cases no hand firing whatever was needed. This would illustrate the reduction in physical labor of the firemen, and, as the fire door is open very little, the heat in the cab is so reduced that the fireman can follow the locomotive trip after trip, almost, if not quite, as regularly as the engineer. Another rather interesting advantage came with the use of the stokers on these engines, in that since the tonnage rating has been raised for those that are stoker-fired there is great rivalry as between hand-fired and stoker-fired engines of the same class, and within the past year or eighteen months the rating of the hand-fired engines has been materially increased, but, as this has been raised, the tonnage rating on the stoker-fired has also been still further increased until on some divisions it is now one thousand tons per train more than was given the hand-fired engines before any stoker engines were received, and is still at least 500 tons higher than any hand-fired engine.

It was also found not practicable to run shovel-fired and stoker-fired locomotives on the same division, even with the less tonnage, as the speed of the hand-fired was so much less that they could not keep out of the way, and now all trains on the different divisions are generally either stoker-fired or hand-fired. In one case, on three divisions adjoining making a total distance of something like 450 miles, all of the freight power is stoker-fired.

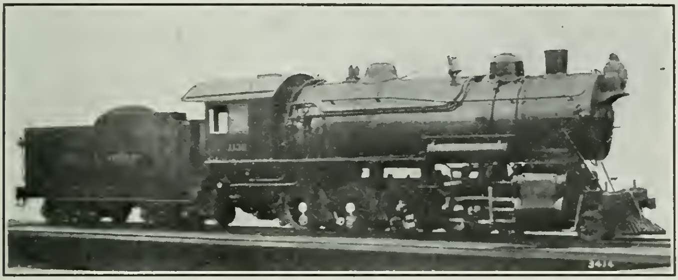


Chesapeake and Ohio Mikado.

This is one of the largest Mikado locomotives in service to-day, having a tractive effort of 60,000 pounds and a grate area of 66.7 square feet.

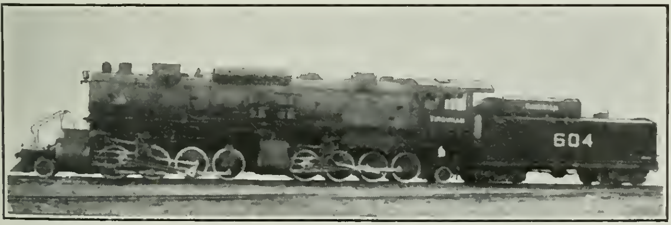
In answer to the question, "What size or class of locomotives should have stokers?" it can be said, first, that under average conditions any locomotive, freight or passenger, which has a maximum tractive effort of 50,000 pounds or burns 4000 pounds or over of coal per hour for an extended period, one hour or over, should be fired with the stoker.

This locomotive was designed on the basis of requiring approximately 120 pounds of coal per square foot per hour for its maximum capacity, or about 8000 pounds per hour. This, with a tractive effort of 60,000 pounds, would then theoretically bring this locomotive well within the stoker class. In practice this also proves correct, as on a certain division equipped with these locomotives the stoker-fired rating is 6000 tons, and if, for any reason, the stoker should be inoperative, the official rating is 4800 tons. Fifty of these locomotives were equipped with Street stokers during the summer of 1912, and they therefore have been in service long enough to secure records of mileage per mechanical failure, cost of maintenance, kind of coal suitable or available for stoker firing, and dynamometer car tests have been made which confirm the above statements as to comparative rating possible between stoker- and hand-firing.



Norfolk and Western Class M-2 locomotive.

This photograph is of interest as showing one of the smallest locomotives to which stokers have been applied. The tractive effort is 52,400 pounds and there are but 44.7 square feet of grate area. This is one of the locomotives on the Norfolk and Western that was used before the arrival of the Z-1 and Z-1-A Mallets, which are now hauling nearly twice the tonnage this locomotive was able to handle. The grate area of this locomotive is rather small for the boiler plant, and therefore it is a hard locomotive to fire as compared with others of similar size, and stokers have been applied to some fifteen or twenty of them—four or five Street stokers and twelve or thirteen Standard stokers. In this particular case the necessity for the application of the stokers might be questioned, although the engines can undoubtedly be worked harder and much relief is afforded the fireman from labor and heat.



Photograph of Virginian Mallet.

This is the largest road Mallet engine ever built, having a tractive effort of 115,000 pounds and a grate area of 99.2 square feet—the latter about the same as the Baltimore and Ohio Mallets. Six of these locomotives are in service, all being fired with the Street stoker.

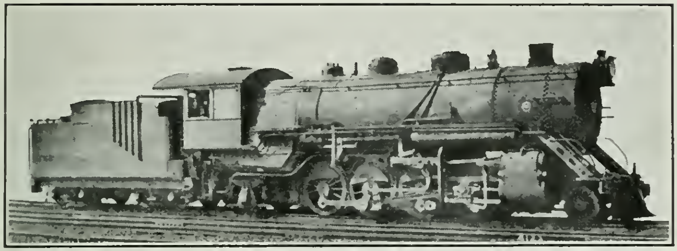
When these locomotives were built, some three years ago, the mechanical stoker was not enough of a certainty to warrant the use of a firebox longer than eleven feet, whereas it is, I think, a safe prediction that eventually locomotives of this size and larger will be designed to be stoker-fired and have fireboxes with grate area nine feet wide and fourteen or fifteen feet long, eleven feet being the admitted limit for hand-firing.

I am showing you practically all of the stoker-fired locomotives that there are, and all of them were designed to be both stoker- and hand-fired, which set limitations that will disappear later on.

Photograph of El Paso and Southwestern Consolidation.

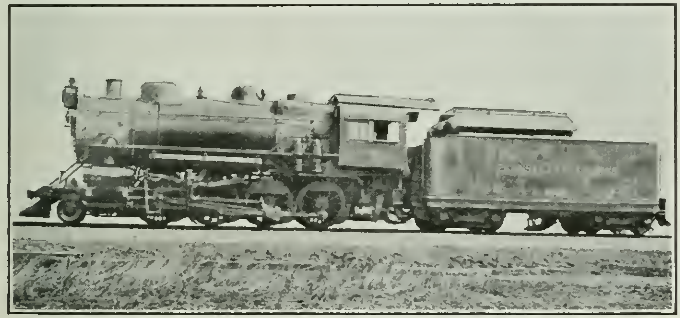
This locomotive is shown in this series particularly on account of size. It is just the opposite of the one last shown, and is about the smallest to which any number of stokers have been applied to date. The tractive power is 49,988 pounds and the grate area 49.5 square feet. Twenty-one of the locomotives are being fired with the Street stoker, mainly on account of the climatic conditions in the desert country of Southern Arizona, which makes it impossible for the firemen to, at all times, fire even this rather small locomotive to its maximum rating.

This is another very large Mikado locomotive. The first installation in the Western territory of mechanical stokers to handle the mine screenings from Illinois coal fields was made on thirty-five of them by the Chicago, Burlington and Quincy Railroad early last year.



Photograph of Chicago, Burlington and Quincy Mikado.

It was found possible to use screenings from nearly all of the mines, and at the same time secure the very satisfactory tonnage increase of from 500 to 700 tons per train over the same locomotive hand-fired.



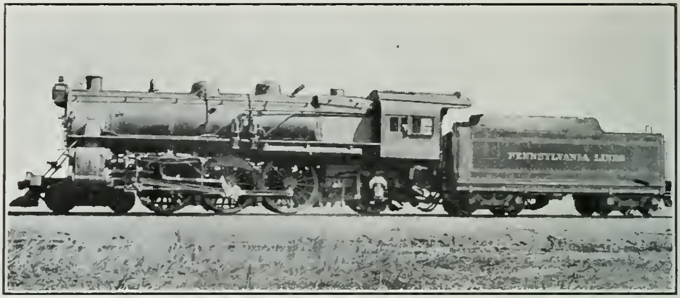
Photograph of Pennsylvania Lines H-10-S Consolidation.

This locomotive is of particular interest as having the Crawford underfeed stoker on over three hundred of them.

It is what might be called a medium-sized locomotive, having 55.12 square feet of grate area, 26 x 28 cylinders, 229,900 weight on drivers, and a rated tractive effort of 50,069 pounds. This latter is a low figure on account of the factor of adhesion used in determining it, being something like 4.95 or 5 as compared with 3.9 to 4.2 usually taken. As a matter of fact, this was taken advantage of by increasing the cylinders from 24 x 28 to 26 x 28 when it was found that the boiler plant could be forced enough harder with the stoker to supply steam for the increased cylinder volume.

The coal supplied for stoker-firing is the same as used on the hand-firing power, the stoker handling the large lumps by crushing as explained.

Three great advantages have accrued to the Pennsylvania Lines West from the application of this large number of stokers to this class of power. The locomotives have an increased tonnage rating, the firemen are relieved from a large part of their labor and suffering from the heat, and a considerable reduction is made in the amount of smoke.



Photograph of Pennsylvania Lines Pacific K-3-S.

This locomotive represents the largest installation of mechanical stokers on passenger power, nearly one hundred of them being equipped with the Crawford underfeed stoker.

Only eight other passenger locomotives in this country besides these have mechanical stokers.

This locomotive is not a large one for stokers, having cylinders 26 x 26, weight on drivers 190,000 pounds, and grate area of 55.4 square feet, about the size of the Consolidation just shown.

So far as my observation has gone, it would lead me to say that this locomotive and the service in which it is used together make nearly ideal conditions for use of the underfeed stoker.

When a heavy through train leaves Union Station, Pittsburgh, going west, pulled by one of these locomotives, stoker-fired, the work is at a very uniform rate for 188 miles. A very satisfactory balance can be struck between the intervals required for the coking process and the total quantity of fuel required to keep the steam at proper point so that all the benefits of the underfeed scheme of firing are secured, such as capacity, economy, smoke elimination, and the improvement in the fireman's job.

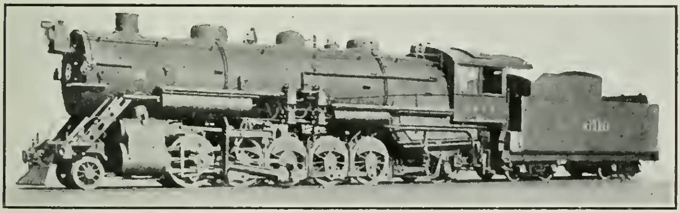
We now come to a type of locomotive that is receiving marked attention by railroad companies, especially since the mechanical stoker became a commercial possibility.

Photograph of Baltimore and Ohio Santa Fé type.

I do not believe it would be claiming too much for the mechanical stoker to say that thirty of these locomotives, on the Baltimore and Ohio, having a tractive power of about 80,000 pounds, cylinders 30 x 32, and grate area of 88 square feet, would not have been built to be hand-fired.

Street stokers were applied by the Baldwin Locomotive Works to the entire lot when built last year.

These are about the largest simple locomotives ever built.



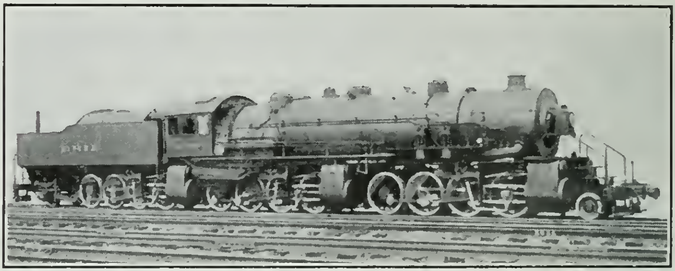
The Chicago, Burlington and Quincy M-2 Santa Fé type.

This locomotive is of special interest as being the very first designed, as to arrangement and dimensions, to be stoker-fired, and is of the same general dimensions as the one just shown, having cylinders 30 x 32, grate area 88 square feet, tractive power of 72,800, and weight on drivers of 301,800 pounds.

Designed in 1911, built in 1912, it was, even at that time, admittedly beyond the physical limits of hand-firing.

The first five of these locomotives were equipped with the Barnum stoker, the first stoker described in this paper. These were later removed, and the Street stokers are now on twenty-seven in service and being applied to fifteen more at the Baldwin Locomotive Works this month.

In daily service these locomotives burn an average of 5500 pounds of slack coal per hour, and for short periods each trip at the rate of 9000 to 11,000 pounds per hour, which well illustrates their being beyond the limits of hand-firing.



Erie Triplex locomotive.

This Erie locomotive, designed by Mr. G. R. Henderson, of the Baldwin Locomotive Works, has received a great deal of comment. It has such new and novel features that it is out of the ordinary.

It is commonly referred to as a Triplex locomotive on account of its having three sets of driving wheels—is three locomotives in one, in fact, and has a tractive power rating of about 160,000—the highest of any locomotive ever built.

The grate area is about the size of the Baltimore and Ohio and Virginian Mallets which we have seen.

Designed to take the place of at least two other locomotives in pusher service on the Susquehanna grade on the Erie Railroad, it requires about 10,000 pounds of mine screenings per hour to fire it to its maximum rating, possibly a little more under certain conditions. It is fired with a Street stoker and is in daily service, doing the work successfully.

In a published interview regarding this locomotive, Mr. S. M. Vauclain, vice-president of the Baldwin Locomotive Works, makes the following statement:

" This type of locomotive would never have been suggested, however, were it not for the fact that we are now able to feed a locomotive boiler any amount of coal up to its capacity to burn it. Thus the human equation heretofore preventing the use of large power units has been overcome, and it is my belief that we are just beginning to enter the field of large power units for freight service of the trunk lines of this country. If it can be proved that we can operate locomotives of 150,000 pounds tractive effort with the same engine crew as heretofore and with less physical exertion on the part of the fireman than with the locomotive of only 50,000 pounds tractive effort, it would appear reasonable that such units of power will be in demand, not only by the railroad companies but by the employees as well."

The fact that more than 1000 locomotives such as I have shown you are being fired with mechanical stokers ought to prove conclusively that the mechanical stoker is no longer an experiment and that it must have some economic value to warrant its application to so great a number of the largest modern locomotives.

What contributes to this economic value?

The use of slack coal or mine screenings for locomotive fuel, for one thing, has a share in it.

We now have enough information about the value of different kinds, grades, sizes, and physical characteristics of coal for locomotive fuel to state positively that the physical characteristics of coal are more important than the chemical analysis. Better results are often secured from coal of inferior quality, but of proper physical form than from that of a better grade in improper size; the variation of evaporation in pounds of water per pound of coal, due to such differences, being identical whether fired by hand or with a stoker.

If, therefore, by the use of a mechanical stoker, all kinds of coal that can be used for hand-firing can be used for stoker-firing with equal economy, and also other kinds and grades of coal become available for locomotive fuel that could not be used for that purpose, the stoker should be given credit for the economic value of a wider market being found for what is a by-product in many districts.

The stoker as a labor-saving device is also of great value not only in the reduction of physical labor and suffering of the firemen, but generally raising the grade of that class of employment, and, while this would not bring about, of itself, a general use of stokers on locomotives, it has its value in the general proposition.

The firemen themselves, as a rule, are favorable to the stoker.

The locomotive engineers, while ordinarily having no interest in the stoker, are just now very much in favor of it.

On one railroad employing nearly one thousand firemen the traffic conditions are such that it has been necessary to " set back " a large number of engineers; that is to say, they must temporarily take the fireman's side of the locomotive, the firemen either being laid off or put on the extra list. Engineers who have not fired a locomotive for several years have a hard time firing under such circumstances: first, because of their physical unfitness, and then, too, because when they served their time firing the locomotives were much smaller than at present. If there is a stoker-fired locomotive on their division and their " rights " entitle them to it, they surely see that arrangements are made for them to be called for the stoker.

The firemen can follow their runs with the same regularity as the engineers on stoker-fired locomotives, and this brings practically the only real criticism the men have against the stoker; that is, that less extra firemen are required in any given district than for hand-fired engines.

The firemen on stoker engines usually make more mileage per month than when hand-firing, with the consequent increase in size of pay check.

As for the need of a second fireman or helper on stoker-fired locomotives, it is now admitted by all, even the officers of the firemen's organization, that where stokers are in successful operation there is no need of—in fact, no demand will be made for—an additional man as asked for on large hand-fired power.

The stoker must eventually have the effect of inducing a better class of men to take up the locomotive firemen's trade. Certain railroad officials consider this tendency, already noted where large numbers of stokers are used, as of great importance.

In searching for all answers to the question, " What is to be gained by the use of mechanical stokers on locomotives? " the really important consideration is that a locomotive is the only thing on a railroad that earns money, and if the stoker can and does remove the limit which is set to the capacity of large locomotives by the inability of the fireman to fire them to their maximum capacity, especially for long periods, then something has been done of economic value not heretofore accomplished.

A brief explanation of why it is almost impossible to hand-fire a large locomotive to its absolute maximum capacity may be of interest here.

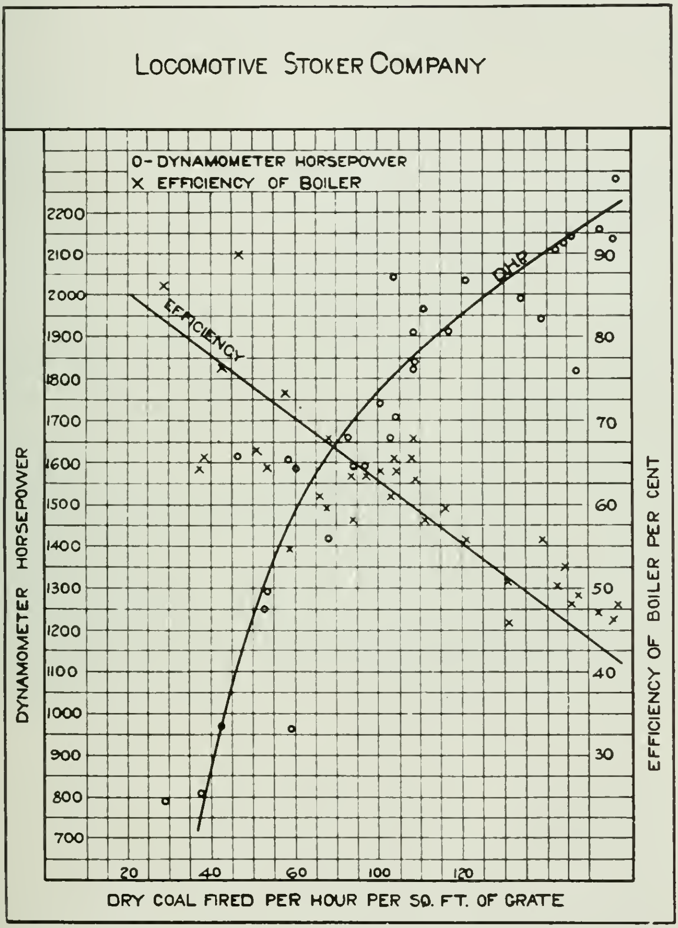


Diagram illustrating boiler efficiency and dynamometer horse-power at different rates of firing.

It is not generally appreciated that the boiler plant of a locomotive differs in many respects from that of a stationary power plant.

The over-all dimensions of a locomotive, which are largely governed by road clearances, centre of gravity, etc., make the firebox of such size, even the largest permissible, that the rate of combustion per square foot of grate area per hour is several times that of a stationary boiler.

This is a diagram illustrating the relation between the efficiency of a locomotive boiler and the dynamometer horse-power developed when burning coal at different rates per hour.

The drop in the efficiency curve is very marked as the horse-power increases. It will be noted at once that the per cent. of boiler efficiency drops off almost in a straight line as the locomotive is worked harder. This will illustrate why it is more difficult in proportion to fire a locomotive as the engineer opens the throttle and drops the reverse lever "over amongst the oil cans," as the enginemen term it.

The average fireman usually is at his limit when the firing rate reaches 75 pounds per square foot of grate area per hour.

The curvature of the dynamometer horse-power line is brought about by the decrease in the amount of water evaporated per pound of coal as the combustion rate increases.

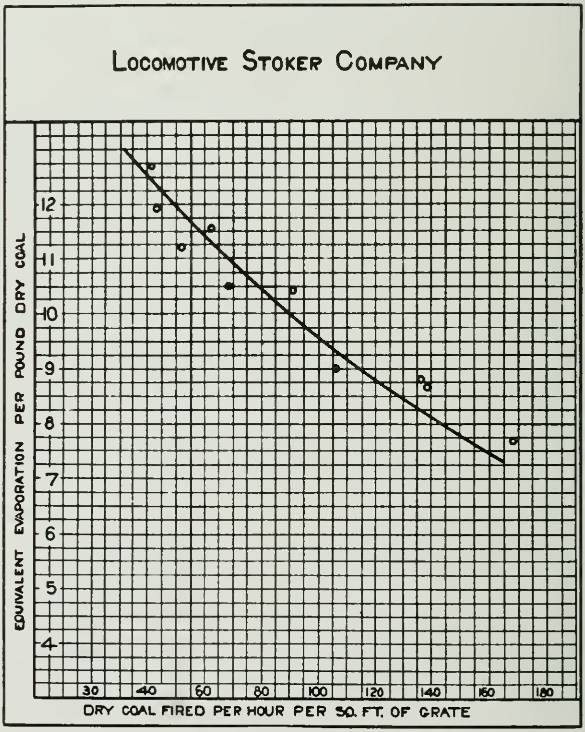


Diagram showing evaporation at different rates of combustion.

This diagram will illustrate the rates of evaporation as the coal fired per square foot per hour increases.

This will also explain why it is sometimes said that a stoker-fired locomotive burns more coal than hand-fired. It does, usually, because worked harder, and it takes more coal to evaporate a pound of water at the point where stoker-fired locomotives are worked.

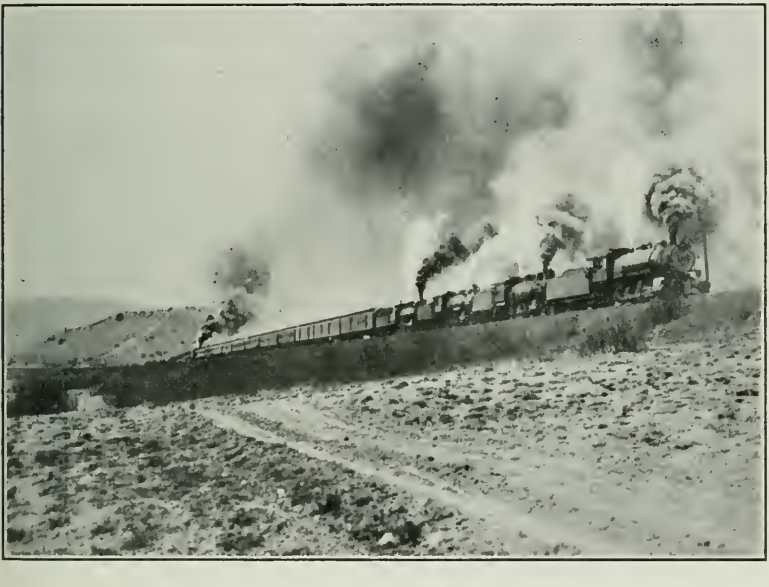


Illustration of stoker conditions in a mountain district.

All large locomotives are not now in a service requiring stokers. On the other hand, there are large numbers of rather small locomotives that are in use where larger locomotives, stoker-fired, could do the work more economically from every point of view. This is an illustration of such a condition: Five hand-fired locomotives on one train, worked hard and not well fired, either, if appearances count for anything.

Larger locomotives can and will be designed, two of which could handle this train.

Locomotive capacity then seems to be the real point in the stoker proposition, even at the expense of some economy in the amount of water evaporated per pound of coal, and what this means in increase of earning power of a locomotive as compared with any increase in cost of coal as the consumption increases per square foot of grate area per hour is illustrated on this diagram.

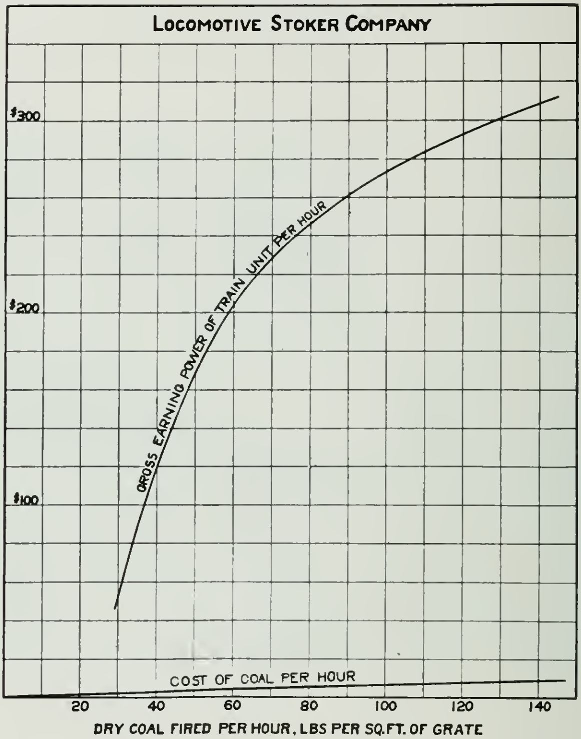


Diagram showing increase in earning power of locomotive as it is worked harder.

It will be seen at once that the increase in earning power is of vast importance as compared with the slight rise in the line showing the coal cost as the locomotive is worked harder.

These curves were plotted from statistics showing freight train earnings when handling such commodities as coal, ore, limestone, etc.—just such lading as is in heavy drag service where stoker-fired engines are used. The coal cost was figured at $1.50 per ton on locomotive tender.

So far as I know, there is not a single case where stokers have been applied by any railroad company that there has not been a material increase in tonnage rating, and in spite of the increase in tonnage there has usually been an improvement in the general smoothness with which the traffic has been moved on the stoker-fired divisions.

To sum up, therefore, mechanical stoking of locomotives raises the efficiency of the locomotive by increasing its earning power, raises the efficiency of labor by making it possible for one crew to handle more traffic per train unit or the same train unit with greater ease, lessens the arduous physical labor and suffering of the firemen, and lifts the grade of his employment; contributing in these and other ways such share of the improvement in the welfare of the individual and the community at large that any labor-saving device must do to be commercially successful.

DISCUSSION.

CHAIRMAN.—The mechanical stoker is the sort of device The Franklin Institute is always in sympathy with, a device that saves money and reduces human suffering to an extent that makes it possible for men to work with comfort to themselves and efficiency to their employers.

I will ask Mr. George R. Henderson to open the discussion.

MR. GEORGE R. HENDERSON (*The Baldwin Locomotive Works*).—Mr. President and Gentlemen of The Franklin Institute: I was very much interested in what Mr. Bartholomew has told us in regard to stokers, but when he says that stokers were not needed before 1912 I think he has gone a little bit too far. For several years before that there were a number of Mallet locomotives built and running in the northwestern part of this country, and when questions are raised as to the difficulty of firing, in keeping these engines hot, it was remarked that there was no trouble and the firemen took it very easy. When we examined these men at work we found it quite true that the firemen did take it easy, and that the engines took it easy. Instead of an engine of double the capacity, we had about the same horsepower delivered as with the smaller engines, simply because the firemen worked up to what they thought was the proper limit, and did not put any more coal in than they used to do on the smaller engines, thus showing the need for a stoker as early as 1907.

It is interesting to note that the stoker which Mr. Bartholomew said had disappeared—that is, of the plunger type—was operating, I think, on the Chesapeake and Ohio in 1904. In 1905 there was a company organized to exploit this stoker, and, in spite of my recommendations to get it out of the cab and bring the coal from the tender by a conveyor, they refused to do any more than sell what they had—it was take it or leave it, and therefore they *left* it, and the company went to pieces.

When you consider the method of blowing coal in by steam, which is the generally-accepted method, it is interesting to note that Mr. Kincaid, in one of his early patents (1909), covered that feature, but I do not think he made any application of it to a locomotive.

Mr. A. N. Willsie (*Chairman, Fuel Economy Committee, C. B. & Q. Railroad, Chicago*).—Mr. Chairman and Members of The Franklin Institute; I appreciate the privilege of being present at this meeting.

I have had practical experience with but one kind of stoker, and that is the Street over-feed stoker. We have sixty-three of these in service on the Burlington road, and some twenty-five or thirty are being applied to new engines.

The time has come when it is necessary to have mechanical stokers on some of the heavy engines now in service and engines that are to be built. While it may be possible to fire these engines by hand, it is not possible to get the maximum amount of work out of the engines, but with the mechanical stoker this is possible.

I am told by men who have had experience with the different kinds of stokers mentioned and illustrated this evening that they are all giving satisfaction, and I have ridden on passenger engines on the Pennsylvania road that were equipped with the Crawford stoker and the work was done satisfactorily.

On the road which I am connected with we have been able to increase the tonnage considerably. This is so with the Mikado type engines, with a tractive power of 60,000 pounds.

The 2-10-2 type, with a tractive power of 71,500 pounds, were designed with the expectation that they be stoker-fired.

It would be very conservative to say that not over ten per cent. of the coal consumed is necessary to be handled by the scoop; in other words, a trip where twenty or twenty-five tons of coal are consumed, not over one ton would have to be shovelled by hand, and oftentimes a great deal less, depending upon the attention the fireman gives the fire and the feeding of the coal.

Some figures were made from actual service for the month of October, 1914, comparing stoker-fired Mikado engines with hand-fired Mikado engines for October, 1913. The average tons of the stoker-fired engines per train was 4326, of the hand-fired engines 3891, or an increase of 435 tons per train. Over a division of 136 miles thirty-one minutes less time was used with the stoker-fired engines, and these additional 435 tons were handled with a few cents less cost for coal; this saving made on account of the price of coal, the stoker engine using 85-cent screenings, while the hand-fired engines were using coal at about $1.20 per ton.

The 2-10-2 type of engines also showed in this same month as handling on an average of 5374 tons, or 1587 more than the hand-fired Mikado engines. The running time over the 136 miles was seven minutes longer than the hand-fired engine, but, as stated before, they handled 1587 additional gross tons, with an additional cost of but 71 cents for fuel.

With the stoker-fired engines it is possible to make better meeting points and get over the road so as not to be tied up on account of the sixteen-hour law. It also makes it possible for the fireman to follow the engine as close as the engineer, thereby making more money than he could possibly make if following one of these large engines hand-fired. This also gets the engine off the road, making room for other trains, and the engine is at a terminal where she can receive round-house attention. It is almost impossible to get over the road within the sixteen-hour limit with the largest type of engines hand-fired, and when the crew are tied up and take their rest wherever they can get it, the fireman especially is not fit to do as good a job of firing after that, and it is always very hard on the engine to be tied up on the road. This kind of work wears the men out, and the company cannot expect but to lose by it.

On one division of the Burlington road, where the heavy power is in service and the business drops off so that it is necessary for the young engineers to go back firing, they oftentimes take the stoker-fired freight engines in preference to hand-fired passenger engines. This results in the good of the service, for the reason that when a young engineer goes back to firing and accepts a passenger run for a few months he is not nearly so well prepared, when he again takes the engineer's position, as he would be had he put in his firing service on a freight engine, as by firing the freight engine he is kept familiar with freight conditions, such as handling long trains and keeping up to date on train orders, etc. This is bound to result in a benefit for the division.

We have also found in one piece of territory that with the mechanically-fired engine we are able to make what we term "turn-arounds," almost without exception, each trip; that is, the crew and engine are used 72 miles and then immediately turned around, returning the same distance. This not only gets the engine back into the terminal where she belongs, gets the crews home where they wish to be, but makes it possible to make this 72-mile turn-around (144 miles) within the sixteen-hour period, which saves over $10 in wages, and figures show a saving of over $7.50 in the cost of coal per trip. A great deal of this saving is caused by the engine not having to be herded around the clinker-pit tracks, fire knocked out, new fire built, and engine again delayed at terminal waiting for a train.

It is not claimed that a stoker engine will save coal over a hand-fired engine unless the engine is of such size as to make it impossible for a man to handle the coal if the engine is worked to her full capacity.

Another point in favor of the stoker engine: There may be conditions where the business has outgrown the present size of locomotive hand-fired, but in order to put in service the largest locomotives it would require many changes in the operating department, such as heavier rail, heavier bridges, larger turn-tables, addition to round-house, and numerous other items.

If the engines in this territory are of such a size as to be up to the limit of hand-firing, it may be possible that the same engine can be equipped with a stoker and get from 10 per cent. to 15 per cent. more efficiency from her. This might result in the engine being handled without any additional expense, as above mentioned. It might make it possible to handle the business over a single track, which would naturally require some double-tracking to handle the same volume if the engines were not equipped to do more work.

I feel quite confident that after the men become more familiar with the stoker-fired engines they will do a great deal better in the matter of fuel economy. On account of the engines being fired with the door closed, it is but natural that they should save coal.

With the stoker-fired engines, also, the fire, as a rule, is so much thinner than hand-fired engines that better combustion is bound to take place, for the reason that oxygen, which is very necessary, comes up through the fire and the air is heated before it comes in contact with the gases, which will naturally make much better combustion than cold air coming in volumes over the fire and through the door when the engine is hand-fired. This light fire will also save delay and expense at terminals, requiring less time to clean the fires.

As stated above, it requires a good fireman to handle the stoker economically, as well as hand-fired, and he is relieved of so much of the physical labor that the railroad company can well afford to insist that he do his stoker-firing properly.

With hand-firing, and with the largest type of engines, the men are inclined to put in too much coal at a time. The door being opened so much not only chills the firebox, but the amount of coal thrown in chills the fire, and it requires some time before the proper heat is again obtained; in other words, it takes about 1200 degrees of heat to distil the gases from the coal, and if the temperature is not up to 1800 degrees the gases cannot burn. Consequently they are taken out through the flues and out of the smokestack unconsumed, or, in other words, just that much heat is lost, and, as the volatile matter of most of the bituminous coal ranges from 25 per cent. to 35 per cent., this waste is enormous. By the door being kept closed and the air necessary for combustion coming through the fire, it seems to me, should result in a great saving.

DR. ANGUS SINCLAIR.—Mr. President and Gentlemen of The Franklin Institute: I am very glad to be here to-night and to have heard that very interesting paper on the mechanical stoker. I have had a great deal of railway experience, and much of my time has been devoted to improvements in firing locomotives.

I began railway service in 1856 with the locomotive superintendent who first applied a brick arch to a locomotive. I was brought into close contact with that invention shortly after it was brought out, and I have always paid particular attention to combustion, and especially to smoke prevention, which means proper firing and proper combustion.

During my time in connection with railways I have seen nearly all inventions of any consequence that have been brought out for improving the operation of the locomotive, and I have never seen anything yet brought out but what there was considerable opposition to its application. Any of you older members who can go back in your minds and follow the various inventions have seen how viciously the new things were opposed. Take the injector, for instance, and follow up other good inventions: they were bitterly opposed at the start. The locomotive men of all the companies that I am acquainted with are particularly conservative, and they object to putting something new on the engine, something that they are not accustomed to, and I think that is the secret—that there has been so much opposition to every improvement.

I have had some experience in running and firing locomotives. I ran locomotives for twelve years, and I always felt satisfied that some mechanical means of firing would be invented and perfected. It is some ten or twelve years, I think it must have been, since I first heard about the mechanical stoker, and I felt so much interested in it that I rode on the engines using them. My judgment of that first stoker was that it was rather imperfect and showed rather crude invention, but it seemed to be capable of improvements that would make it just as successful a device as the injector proved to be. However, the parties who had hold of that seemed to get discouraged at the first opposition. The enginemen were by no means enthusiastic about it. I heard that they expected ordinary laborers to be on the engines to do the work, and that the fireman's job would be at a finish, and my experience with the successful mechanical stokers has been that it requires a more intelligent man to operate the stoker as it should be operated than it does a man to shovel the coal, and I think that as the experience develops with the mechanical stoker it will be much more efficient than it is to-day, and the improvement that comes with practice will still add to this efficiency and therefore add to the economical operation of the mechanical stoker.

I have had quite a busy life. I have ridden on engines equipped with the stoker; I have been on several of them—on the

Street stoker particularly; and I do not think there is any mechanical device in use that works more successfully than it does.

When they talk about waiting for developments of the mechanical stoker, they are talking about something they do not understand. It is as well perfected as any ordinary device, and it will be successful when it is in the hands of its friends.

MR. W. L. ROBINSON (*Baltimore and Ohio Railroad*).—I came in a little too late to hear the entire paper read. We have 222 of these locomotives operating successfully in regular service, and, from what Mr. Bartholomew has read and shown you, there is not much left to say, due to a great deal of what has been stated applying to the operation of the Street stokers on the Baltimore and Ohio. However, I had the opportunity to read the paper carefully before coming to the meeting, and will say that, in so far as the experience of our road is concerned, Mr. Bartholomew has covered the matter very well.

Mr. Willsie has also spoken of the main advantages of mechanical stoking, and there are only one or two things I would care to mention in addition to what has been stated, and they are the question of increased train load and method of carrying the fire on the grates.

In regard to train load, it should be stated that this has increased from eight to fifteen per cent., and the stoker locomotives get over the road very much better and bring about a more uniform performance.

Regarding the method of carrying the fire on the grates, it has been necessary to carry a light, level, and bright fire to get the best results, and this has resulted in very little necessity for grate shaking, raking fires, or dumping ash pans; and I have ridden a great many engines during the past winter when trips were made with full tonnage trains and the fire not shaken or touched by rake or ash pan dumped from one end of the road to the other, and the fire in such condition that full steam pressure was maintained to completion of trip.

All these locomotives are operating in pool service, except on one division where they have recently been assigned to regular crews.

I think about all of the features have been well covered, and it is merely repetition to add to the remarks which have already been made, so far as Street stoker is concerned, and I have had no practical experience with any other type of over- or under-feed stoker.

CLOSURE BY AUTHOR.

From what has been stated in the paper and by those taking part in the discussion it is no doubt very plain that the mechanical stoker for locomotives does not come within either of two classes of labor-saving devices which were referred to earlier in the evening; *i.e.*, those which are applied entirely for the profit to be made on the investment or those which are applied entirely for humanitarian considerations.

It is evident that the railroad companies and the enginemen both profit by the application of mechanical stokers to locomotives.

Locomotive capacity is increased, while, strange as it may seem, the fireman's labor in shovelling coal and his suffering from the heat are materially reduced.

The railroads secure a return on their investment from the increased tonnage, less expensive fuel, and other economies effected, and the men, individually, make more money per month with less effort.

Small locomotives are made larger, and larger locomotives are made possible.

These and other results are being accomplished by stokers designed to be applied to existing power with the necessary limitations that come thereby, and much more may reasonably be expected in the future, now that the stoker has established itself for permanent use, as stokers will be taken seriously into account in the designing of new heavy power to be built in the future for capacity as well as economy.

The Franklin Institute deserves great credit and the hearty thanks of the railroads, the public, and the men who fire the locomotives for the interest taken in the development of devices of this kind which serve the double purpose of contributing to the uplift of the men who work and at the same time have economic advantages sufficient to warrant the necessary investment for their general application.

ON AN UNBROKEN ALTERNATING CURRENT FOR CABLE TELEGRAPHY.*

BY

LIEUT.-COLONEL GEORGE O. SQUIER, Ph.D., M.R.I.,
Fellow of the Physical Society of London,
Member of the Institute.

I. *Introduction.*

THE object of this paper is to propose a new angle of view in the method of transmission of signals in the submarine telegraph cable, and to describe some apparatus for operating on the general principles involved.

Although more particularly an engineering subject, yet it is brought before the Physical Society in the hope that some of its members may see in the plan proposed some points in the fundamental theory of ocean cabling for further research.

The phenomenal progress of wireless telegraphy has been made possible only by the combined efforts of some of the world's best-equipped physicists and the practical engineer. It is in the hope of a similar coöperation of effort for the advancement of cable engineering practice that I invite your attention at this early stage of development.

Experiments have been conducted during the past two years at the works of Messrs. Muirhead & Co. (Ltd.) with a view of determining the practical application of the sine-wave type of E.M.F. for cable signalling. The results thus far obtained have only been made possible through the wide range of experience and practice which this distinguished firm of cable engineers have been able to bring to bear on the subject, and they have taken a leading part throughout the experiments carried out.

Sixteen years ago Dr. Crehore and the author conducted some experiments on an Atlantic cable from Waterville, Ireland, to Nova Scotia, Canada, using a special form of dynamo as a source of power for operating the cable.

A transmitter was also devised, in which a special feature was the cutting out or suppressing from the alternating current certain definite semi-waves of current which enabled the cable code to be transmitted.

---

* Communicated by Colonel Squier.
Read before the Physical Society of London, June 25, 1915.

At that time the demand for increase of speed over ocean cables was not pressing. In fact, the particular cable used was idle for several hours each day, which fact, however, greatly facilitated the opportunities for experimenting.

Wireless telegraphy did not then exist, and the cable relay or amplifier had not appeared, so that very accurate balancing of the duplex bridge was not required.

Conditions have changed materially since 1899, until at the present moment it may be said that the matter of obtaining increased speed on ocean cables with present apparatus is largely controlled by the accuracy with which the duplex bridge may be balanced.

II. *An Ocean Cable Considered as a Power Line.*

If an engineer were required to design a system for operating an electric motor through an Atlantic cable, no form of generator could be proposed at present, other than a single-phase alternating current of the sine-wave type. This form, we know, will deliver power at the receiving end of the cable more efficiently than any other shape of wave. Furthermore, during the operation of such a motor, the generator would be allowed to run smoothly and regularly, and, in particular, the generator circuit would never be metallically opened or closed during operation.

The opening and closing of an alternating-current circuit is well known to produce disturbances of a more or less pronounced character, depending upon the angle of phase at which the current is opened or closed.

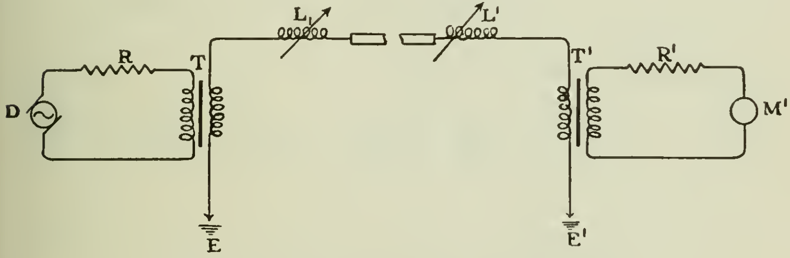
Since improvement of the duplex-bridge balance, as stated above, is really at present a most important desideratum, experiments were made using the Muirhead artificial cable to compare the present forms of battery transmitters with various modifications of the sine wave of E.M.F.

In the last analysis it was always the opening and closing of the transmitter circuit which produced the final kick or " jar " in the balance. This is not surprising when we remember that, from an electrical standpoint, few things can be done to a circuit more severe than to suddenly introduce an infinite resistance into it.

However, since there is an appreciable spark or arc at the instant of opening the battery transmitter circuit, this discharge controls to a greater or less degree the character of the break; but the exact influence of this is not so easy to predict, for, though it is probable that the current dies away quicker with a sudden break than it does with a very slow one, which permits the arc to remain for some time, yet it is not proved certainly, for the more rapidly the break is made the faster the resistance increases, and therefore, probably, the rate of change of current, and with it the counter E.M.F., increases. An increased E.M.F. can bridge a longer gap, but a longer gap may be made in the same time that a short one is, with a less velocity at the break. So it appears that these two considerations counteract each other, and it all depends upon which has the greater influence.

It was only after many variations of the simple alternating current had been tried in the course of experiments to perfect the duplex balance of the bridge that the fundamental principle of never breaking the transmitter circuit became impressed.

FIG. 1.



Simplex circuit for ocean cable considered as a power line.

Continuing the analogy of the power plant, it may be remarked that practically every form of cable recorder, amplifier, or relay is essentially an alternating-current motor. Its field magnets, armature coil, and the counter E.M.F. of damping are subject to the same laws as in the motor for power purposes.

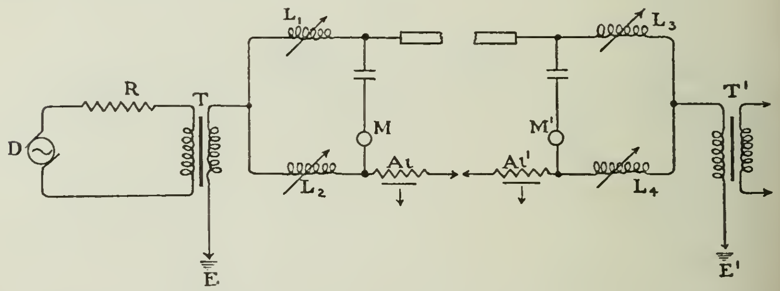
Let us assume, therefore, as a starting point, the standard type of circuit for operating a cable simply as a power plant as the ideal solution of the problem, and then determine by experiment how near this solution may be retained in practice for the purpose of transmitting cable signals according to the present alphabet. In this plan it will be the continued experimental purpose to determine the minimum possible variations in such a system to enable the alternating current received to be interpreted into dots, dashes, and spaces.

A siphon recorder placed in the receiving end of such a cable plant would trace on the recording slip an uninterrupted sine wave of current which may be considered as the theoretically perfect form of siphon record always to be aimed at, although never to be actually attained in practical telegraphy.

In Fig. 1, D represents a single-phase alternating-current dynamo, R and R' are resistances, and M' is a motor to be operated.

Since a circuit comprising an ocean cable is largely overloaded with capacity, and already includes a large ohmic resistance, it will be in the direction of increasing the resultant harmonic current flowing in such a circuit, to insert in the sending end of the cable a variable inductance, L_1. For symmetry, L' is a variable inductance similar to L_1.

FIG. 2.



Duplex circuit for ocean cable considered as a power line.

T and T' are iron-cored transformers or auto-transformers, the coils of which are of low resistance, and connected directly to earth at E and E'.

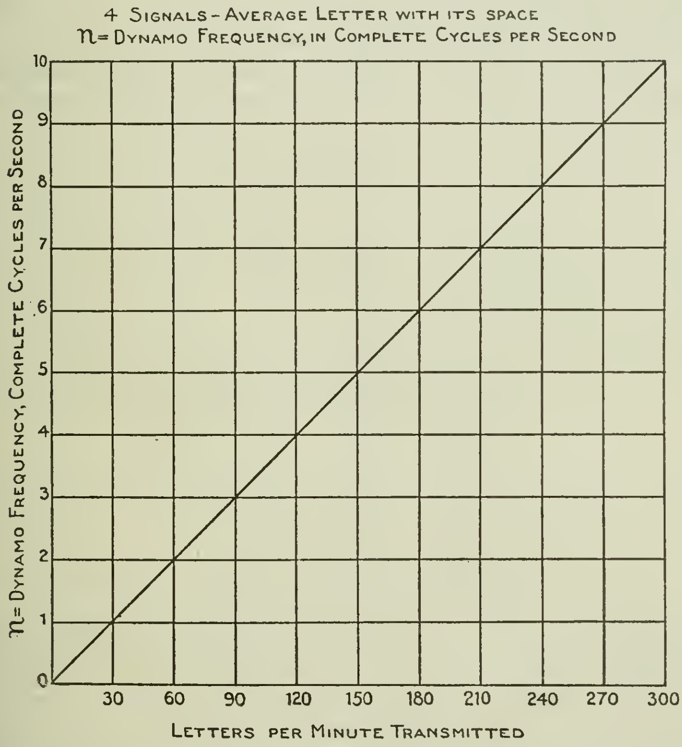
The circuits in Fig. 1 are closed circuits throughout.

For duplex working Fig. 1 becomes Fig. 2, in which L_1, L_2, L_3, L_4 are the inductance arms of the bridge, and the motors M and M' are inserted in the usual manner for cable working; Al and Al' are the artificial lines.

It now remains to inquire as to what modifications must be made in the typical duplex power circuit in Fig. 2 to enable the motor recorders to indicate the elements of the cable alphabet. These elements are three in number, and only three—*i.e.*, the dot, the dash, and the space—and each of them is equally important in interpreting the record, and for this reason they will each be considered in the general sense as signal units, rather than the usual way of regarding only the dots and dashes as the signals, and not the spaces.

It is also usual to speak of cable speeds in terms of standard letters per minute transmitted; but for our present purposes it will be more convenient to convert this speed into terms of the frequency of the dynamo. The graph (Fig. 3) exhibits the linear relation between *n*, the frequency of the dynamo, and letters per minute transmitted, based on the assumption that the average cable letter, with its space, requires four units of alphabet time.

FIG. 3.



Speed of cable signalling in letters per minute in terms of the frequency of the alternator.

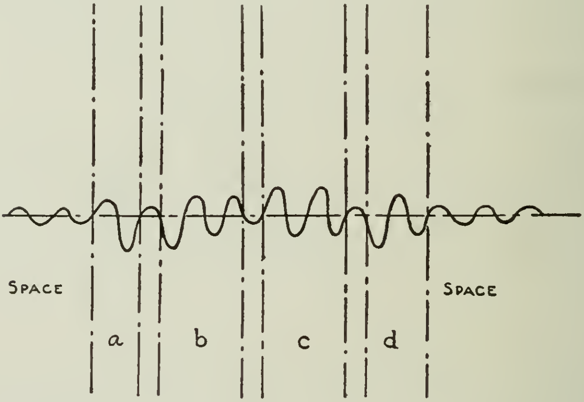
Careful experiments on an Atlantic cable confirm the theory of the subject—that, no matter what the shape of the alternating current transmitted, approximate sine waves are received at the distant end of the cable. Battery reversals produce just as accurate sine-wave signals on the receiving recorder as does the alternator itself.

In other words, it is the fundamental term of the Fourier analysis which is alone concerned in making the record at the receiving end of the cable.

Since, therefore, both theory and experiment show that a sine form of wave is the only one which can pass through the cable without changing its characteristic shape, it should be an advantage to so alter the typical power circuit in Fig. 2 as to preserve the sine characteristic as far as possible.

This can be done in a simple manner by operating upon the primary circuit of the transmitter containing the generator, to alter the impedance of the circuit in synchronism with the generator itself. The problem is the more simple from the practical standpoint, because we are dealing with frequencies from about four to ten cycles per second, and, therefore, it is easy to operate with great accuracy on this primary current at any angle of phase. If the change of impedance of the primary circuit always takes place at the instants when the current flowing in the circuit is naturally zero, the fundamental frequency of the current will not be changed, and the sine characteristic of the wave will be very approximately maintained. Varying the impedance of the primary circuit will change the amplitude of the individual alternations of the current.

FIG. 4.



Current waves for transmitting the letters *a*, *b*, *c*, and *d* by the alternating current.

Another way of stating the effect is that the voltage between the end of the cable and the earth is made to vary by this process, to indicate the three elements of the cable alphabet. It should be noted that this plan transmits alternating current for the spaces between letters and words with exactly the same regularity and integrity as for the signals themselves.

Dots, dashes, and spaces are each transmitted by impulses of either sign, differing from each other only in amplitude.

Fig. 4 shows diagrammatically the form of current waves transmitted for the letters *a, b, c,* and *d* with the accompanying spaces required.

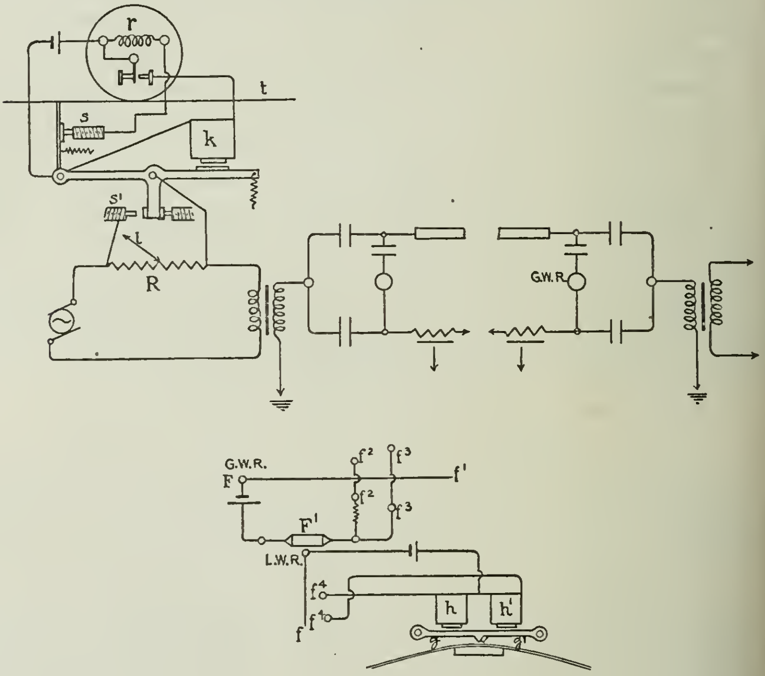
Although an alternating current operated upon as above outlined could be read directly from a standard siphon record, yet it would be considered an advantage if the final received record could be printed in Morse characters on the usual receiver slip. To accomplish this it will be necessary to provide an apparatus which operates solely by the amplitude of the current waves received, and not by their sign. Furthermore, since the impulses transmitted and received for the spaces are not required on the printed slip, the apparatus should be capable of sorting out and omitting these parts of the record automatically.

Description of Circuits Used.

Fig. 5 shows diagrammatically one form of circuit arrangement based on the above principles for transmitting and receiving messages. The usual transmitting condensers are shown in the arms of the duplex bridge, instead of the inductances L_1, L_2, L_3, L_4. The ordinary transmitting tape is caused to move synchronously with the generator by being geared directly to its armature shaft. The perforations in the tape are of such a size that the tape advances a distance corresponding to one semi-cycle of the alternator for each individual perforation.

Since in a circuit comprising an ocean cable on which is impressed an alternating E.M.F. the current leads the E.M.F. by an angle which in an infinite cable is constant at 45°, it is necessary to provide in the transmitter mechanism for moving the tape carriage longitudinally relative to the perforations in the tape. A micrometer screw is provided for this purpose, and by its use the current can be operated upon accurately at any angle of its phase, and in practice it is so adjusted that the impedance of the primary circuit will be changed at the instants of zero phase of the current. Since also the angle by which the current leads the E.M.F. is dependent upon the resistance of the primary circuit, there is also provided in addition an adjustment of the transmitter for the very slight difference of phase for the dot-and-dash conditions, so that in effect all operations on the primary current, whether for a dot, dash, or space, are adjusted to take place at the zero point of current.

FIG. 5.



One form of duplex circuit arrangement for transmitting and receiving messages by the alternating current.

The general operation of the transmitter mechanism is as follows: When no holes are perforated in the tape *t*, the whole resistance *R* is in the primary circuit and an alternating current is transmitted, which corresponds to spaces between letters and words, and when a perforation in the tape is on the dot side, part of this resistance *R* is short-circuited, and when a dash perforation occurs, all of this resistance is short-circuited. The relative values of these resistances being adjustable, the amplitude of the individual alternations is under complete control by the ordinary transmitting tape.

In the figure is shown diagrammatically the arrangement for causing a dash impulse to be sent by the transmitter by short-circuiting the whole of the resistance R for a time corresponding to one semi-cycle of the alternator. r is an ordinary relay, k is an electromagnet which operates at the end of each signal or group of signals. The line l leads to an exactly similar arrangement which is provided for the dot impulse by which a certain proportion of the resistance R is short-circuited. In practice these two arrangements are side by side, and in the figure the dot arrangement would be immediately behind the one shown for the dash.

The tape carriage can be moved longitudinally by a micrometer screw which is not shown in the figure, and has an adjustment over a range of a complete semi-cycle. The contacts s and s', and similar ones for the dot mechanism, are adjustable by slow-motion screws, so that the instants of contact for a dot and dash have an adjustment relatively to each other.

A convenient method of observing the wave-form produced by the transmitter, and for making the above adjustments, is to include an ordinary siphon recorder in the transmitter circuit, or, better, in the cable itself at the transmitting end; by connecting it at the terminals of a very low resistance in the circuit. At the very low frequencies involved, the siphon recorder becomes a most useful and accurate current curve-tracer, and enables the experimenter to observe exactly the shape of wave being transmitted into the cable for any adjustment of the transmitter. Once these adjustments are made for any particular cable they remain unchanged.

Form of Receiving Circuits.

One practical arrangement for receiving the signals on a Morse printer is shown diagrammatically in the upper part of the figure.

F is an adaptation of the well-known Muirhead gold-wire cable relay, in which f' is the gold wire which oscillates between the platinum contact posts f^3f^3, about a fixed point at F. A second pair of posts f^2f^2 is provided, and each of these pairs has an adjustment for altering their distance apart and also for moving them longitudinally along the gold wire and relatively to each other. Instead of being separate contacts, as in the usual case with this relay, each of the pairs are electrically connected as shown. F' is a local wire relay of similar principle, and f is its moving part which in its oscillations makes contact with the posts f^4f^4 adjustable as above; h and h' are electromagnets for operating the dot and dash arms of the printer; g and g' are two arms pivoted at their outer ends, adapted to make a siphon record at their free ends in the centre upon the moving tape shown beneath. The arm g' is forked to record two ink marks on the tape symmetrically on either side of the central mark made by the arm g, and in line with it across the tape, so that both arms can make a record simultaneously on the tape for a dash.

The incoming alternating current thus causes the gold wire f' to oscillate back and forth with different amplitudes depending upon whether dots, dashes or spaces are being received, and the posts f^2f^2 are adjusted so that the space amplitude just does *not* make contact, but does make contact for a dot amplitude of either sign. In like manner the posts f^3f^3 are adjusted so as just *not* to record a dot impulse, but to make contact for the larger amplitude of a dash of either sign. It is seen that both a dot and a dash contact are made whenever a dash amplitude is received. The flexible gold wire f' in its motions about F first strikes the posts f^2f^2, and there is a bending or wrapping effect produced in the wire, which for the stronger dash impulses causes contacts with f^3f^3 also. The relay F' operates similarly through a moving arm, making contact with the posts f^4f^4 separately or both together, depending upon the amplitude of its swing.

The printer itself becomes an apparatus of marked simplicity, and is nothing more than two small siphons adapted to mark on the slip in the usual manner.

In practice, all adjustments are so made as to provide for transmitting for the spaces as large an amplitude as possible instead of as small an amplitude as possible, in order to approximate more nearly to the ideal electrical conditions for transmission through the cable itself.

In case a cable magnifier such as the Heurtley instrument is used instead of a gold-wire relay, it would be inserted in Fig. 5 in the recorder arm of the bridge, and operate a local wire relay and printer instead of the usual recorder. Since the relay operates on difference of amplitude of the waves, and not on their absolute value, a cable magnifier would serve to exalt the value of this difference and furnish a greater margin for practical working.

Resolving Power or Definition.

The ideal alphabet to employ in cable signalling would be one in which, other things being equal, each letter had the same limit of legibility; because if this is not so, the speed of signalling is lowered to meet the legibility of certain letters only. In present cable practice, what may be called the " resolving power," or the definition, is not equal throughout the letters of the alphabet.

Letters like " a " or " n," for instance, may be considered as perfect letters, and whether sent by one complete cycle or E.M.F. of a dynamo, or by two square-topped waves of equal area and opposite sign separated by a time interval, produce on the siphon record approximate sine waves. On the other hand, letters like " s " or " h," where three or four square-topped waves of the same sign are sent into the cable consecutively, the received record at high speed fails to resolve these separate impulses, and the siphon record becomes a more or less continuous hump of large amplitude, which the expert operator learns to read without being able to detect the individual impulses; in fact, some practical operators seem to prefer these letters to what are known as " cross-letters," such as " a " and " n."

Careful experiments have been conducted through long cables, which prove, however, that the so-called " cross-letters " have a superior legibility, which obviously should be the case from theoretical considerations only.

We may consider the siphon record of an uninterrupted alternating current as possessing 100 per cent. definition, independent of the frequency, the voltage employed, or the particular cable used, and regard it as the standard of definition for all signals. Indeed, such a record is, in fact, a message composed of a series of the letter " a " joined together without spaces between.

In present practice it is found necessary to insert a receiving condenser in series with the recorder coil, or an inductive shunt around the coil, for the purpose of improving the definition of certain letters of the alphabet, such as " s " and " h," as well as to eliminate from the record the effects of earth currents of very low frequency induced in the cable.

III. *Electrical Measurements of the Cable Circuits.*

One of the chief attractions in the use of an unbroken alternating current for operating the cable is the fact that for the first time we are enabled to measure the constants of the different elements of the bridge and cable circuits employed under actual signalling conditions. Since one particular frequency is used and the current is never broken, it is necessary and sufficient to use the ordinary commercial hot-wire ammeters and voltmeters which are now available over suitable ranges.

A tachometer is attached to the dynamo armature shaft, so that the frequency is indicated continuously, and these readings, in connection with those of the ammeter and voltmeter, are all that are required to determine the impedance and phase angle of any part of the transmitter circuit, including those of the cable itself.

In the present forms a battery transmitter a square-topped wave is employed, and, in addition, it is found necessary to disconnect the battery and connect the cable to earth during a portion of each individual signal sent. The reason for this is that, in this form of wave, the cable receives a charge dependent upon the time during which the key remains closed for the signal, and when the circuit is opened it is necessary to give time for the cable to become discharged before the succeeding signal can be sent. This discharge is shown in the spark that is seen in the present form of transmitter when the circuit is broken. The percentage of time of each elementary signal during which the cable is connected to earth varies according to the cable, but in long cables it is usually about 25 per cent. of the whole time of the signal.

This means that of necessity the cable is entirely disconnected from the battery at both ends for a period aggregating six hours per day, due to the present method of sending the individual signals.

This discharge of the cable has, indeed, been turned to account for a useful purpose by the late Mr. Gott,[1] who quite recently developed a system of transmission in which the discharge of the cable is ingeniously utilized to operate the tongue of a relay, which causes the succeeding signal to enter the cable with the opposite sign.

This form of square-topped wave, when combined to make up letters and words, causes a broken and irregular form of current to enter the cable, which precludes the possibility of measuring the ordinary quantities, such as voltage, current, impedance, and phase-angle of the different elements of the circuit. This is extremely unsatisfactory from an engineering standpoint, and retards progress.

---

[1] British patents No. 10,534 and No. 22,364 of 1912.

The development of the modern artificial line for simulating the action of the cable has required a large amount of patient and careful work extending over a number of years. As soon as any form of break, with its consequent spark or arc, is removed from the transmitter circuit, and an alternating current of one frequency only is substituted, the artificial line can more faithfully represent the action of the current flowing in the real cable, and its construction may be simplified.

Transmitting Impedance of an Atlantic Cable.

In the case of long submarine cables having resistance and distributed capacity, self-induction and leakance being neglected, we have the well-known sine-wave formulæ for an infinite cable:

$$e = E\varepsilon^{-\sqrt{\frac{CR\omega}{2}}x}\sin\left\{\omega t - \sqrt{\frac{CR\omega}{2}}x\right\}, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$i = E\sqrt{\frac{C\omega}{R}}\,\varepsilon^{-\sqrt{\frac{C\omega}{2}}x}\sin\left\{\omega t - \sqrt{\frac{CR\omega}{2}}x + \frac{\pi}{4}\right\}, \ldots\ldots\ldots\ldots(2)$$

e and i represent instantaneous values of the voltage and current at any point of the cable at a distance x from the origin and a time t: E is the maximum value of the E.M.F. applied to the cable, R and C are the resistance and capacity of the cable per unit length, w is 2π times the frequency.

These formulæ are accurate for all practical purposes in the case of long cables, as will be shown presently.

At the transmitting end of the cable $x = 0$, and (2) becomes

$$i = E\sqrt{\frac{C\omega}{R}}\sin\left\{\omega t + 45^\circ\right\}, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

$$i = I\sin\left[\omega t + \theta\right], \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

where I is the maximum current and θ is the angle by which the current leads the E.M.F. This angle is constant and equal to 45 degrees. The transmitting impedance of the cable is

$$Z_1=\frac{E}{I}=\sqrt{\frac{R}{C\omega}}=\sqrt{\frac{R}{2\pi C}}\sqrt{\frac{1}{n}}=c_1\sqrt{\frac{1}{n}}\ \ldots\ldots\ldots\ldots(5)$$

where c_1 is constant for any particular cable.

$$I=\frac{E}{Z_1}=\frac{E}{c_1}\sqrt{n}\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

Let us assume

$R=4{,}895$ ohms.
$C=914.10^{-6}$ farads.
Length $=2{,}164$ knots

which data represent one of the best transatlantic cables.

Substituting in (5) and (6) we have

$$Z_1=\frac{923.2}{\sqrt{n}},\ \ldots\ldots\ldots\ldots\ldots\ldots(7)$$

$$I=\frac{E}{923.2}\sqrt{n}\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

The graph (Fig. 6) represents the impedance-frequency curve at the transmitting end of this particular cable plotted from (7).

For $n=5$, or at 150 letters per minute, the cable impedance is 412 ohms, or only 8.4 per cent. of the ohmic resistance of the cable.

The impedance of this same cable, as measured by the ammeter-voltmeter method, for a frequency of $n=5.03$ is 397.5 ohms.

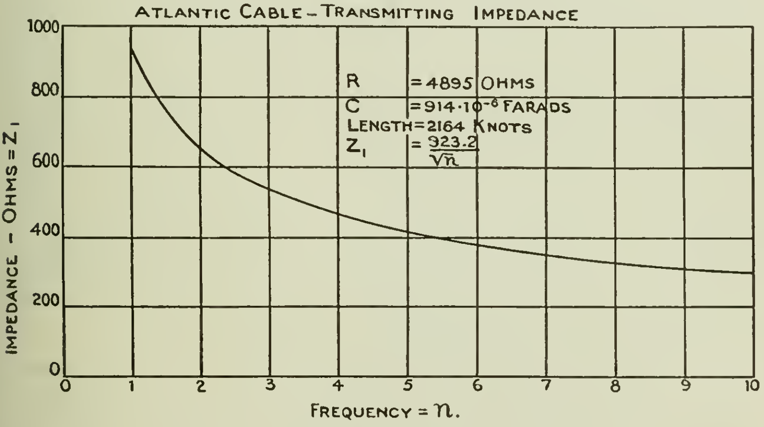
With 50 volts on this cable at the same speed of transmission the current flowing into the cable from (8) is

$$I=0.12 \text{ ampère.}$$

The transmitting impedance is most sensitive to change of frequency at the lower frequencies, and by increasing the speed from $n=4$, or 120 letters per minute, to $n=9$, or 270 letters per minute, the cable impedance is decreased in the ratio of 3 to 2, and the current correspondingly increased. The same values of impedance and current deduced above apply to the equivalent artificial line, which is made to balance as far as possible the real cable.

By inserting a hot-wire ammeter in the cable itself beyond the bridge, and also connecting the transmitting end of the cable to earth, through a suitable voltmeter (preferably an electrostatic instrument, to prevent any disturbance of the bridge balance), we have the means at hand for determining the best transmitting conditions for any particular cable and frequency of signalling. Heretofore the value of the transmitting condensers in the duplex arms of the bridge have been more or less arbitrarily assigned by certain practical rules obtained by an expert study of the signals themselves. Here, however, we may approach the problem more scientifically by so adjusting the values of the condensers or inductances, or both, in the bridge branches as to produce a maximum reading of the hot-wire ammeter in the cable itself for any particular voltage assigned. The criterion for best transmitting conditions alone would be that the transmitting impedance should be a minimum, or the current flowing into the cable as measured by a hot-wire ammeter should be a maximum for any particular signalling frequency.

FIG. 6.



Transmitting impedance of a transatlantic cable as the speed of signalling is varied.

This practical method is, of course, entirely analogous to the present practice of inserting a hot-wire ammeter in the transmitting antenna of a wireless station, except in the latter case we can go much further and adjust for the maximum current possible at the maximum point of the resonance curve of the antenna. In the cable circuit we are dealing, not with resonance, but with forced waves maintained by the dynamo.

Electrical Stress Upon the Cable.

Submarine cables are at present operated by primary batteries giving an open-circuit voltage of from 50 to 80. The main reason for this is, of course, the constant fear of subjecting the cable itself to undue electrical strain, particularly in the deep-sea portion, where repair is difficult and expensive. This is not the only reason, however, although it is the principal one.

The present form of battery transmitter impresses upon the cable square-topped waves, which may be analyzed by Fourier's method, and in the hands of Malcolm and a few others the wave form can be worked out and predicted as the wave passed through the cable to the receiving end. Since we know that it is only the fundamental term of the Fourier analysis which produces an appreciable effect at the receiving end, all of the harmonic waves which are required to build up the square-topped form of wave are impressed upon the cable at the transmitting end, and are absorbed in the cable itself, and never reach the receiving end. These, therefore, represent superfluous electrical charge impressed upon the cable, and this charge for each signal must be got rid of before the succeeding signal can be sent into the cable.

It is, therefore, probable that a practical limit would soon be reached in the present form of transmitter, where the magnitude of this extra charge sent into the cable would become so great that there would be little advantage in further increasing the E.M.F.

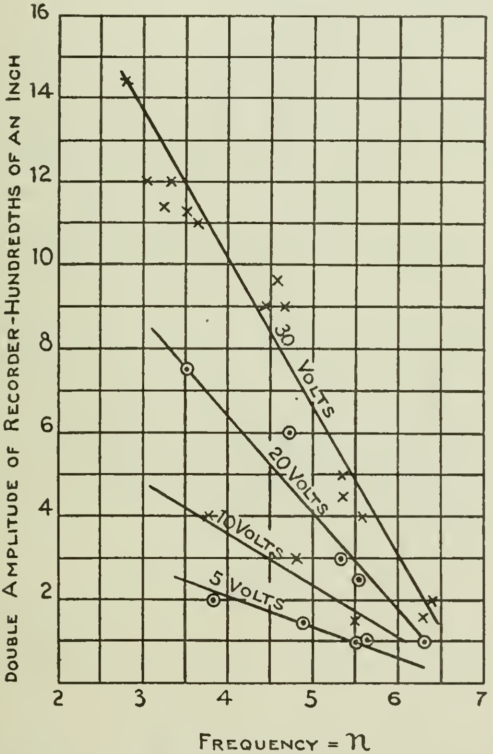
The direct influence which increase of voltage produces on the amplitude of the record received as the frequency changes is shown in the graph (Fig. 7). These data were obtained over a submarine cable from New York City to Canso, Nova Scotia, of

$$\begin{aligned} R &= 13{,}700 \text{ ohms.} \\ C &= 231.4^{\circ}10^{-6} \text{ farads.} \\ \text{Length} &= 880.6 \text{ knots.} \end{aligned}$$

The cable was used at the transmitting end simplex, without condensers, and at the receiving end the ordinary duplex arrangements were employed with 50 mf. condensers, and the cable recorder was adjusted once for all, and remained unchanged throughout the experiments. The receiving arrangements were not particularly sensitive, and the recorder was not readjusted as the frequency was increased.

It will be observed that, within the limits of these experiments, the amplitude of the excursions of the siphon increased with the voltage for any particular frequency of the dynamo, and as the frequency was increased, the voltage remaining constant, the double amplitude of the siphon record gradually decreased. Theoretically, these lines are curved lines, but for observations up to 30 volts, with but one adjustment of the recorder, the right lines in this figure best represent the actual observations at each voltage.

FIG. 7.



Variation of double amplitude of siphon record with change in frequency, voltage constant.

It is seen that these lines converge toward a common vanishing point at somewhere about $n = 7$, which means that, with the limited sensibility of the particular recorder used (which may be considered as an ammeter if properly calibrated), we cannot expect by any increase of voltage to signal faster than about $n = 7$ with this particular cable.

This graph has been made from data of experiments made 17 years ago, and since that date, due to the great improvement in sensibility of cable relays and amplifiers, the vanishing point at the present day for this cable would be moved to the right along the axis of abscissa, to some point corresponding to n equal a considerably larger number than 7.

The above outline will be sufficient to show that in the case of an alternating current being impressed upon a cable, increase of voltage for signalling purposes should be considered from a new point of view, for we know that the power impressed in this case varies directly with the square of the voltage used in transmitting.

Maximum Voltage Along the Cable.

In (1) and (2) above, it is seen from the exponential factor that the maximum ordinates of the E.M.F. and current waves decay according to the logarithmic law, and that the rate of decay is dependent upon the capacity and the resistance of the cable per unit length, and also upon the frequency.

Assuming $n = 5$, or 150 letters per minute, the instantaneous value of e or i, and also the maximum volts per volt at sending end have been computed for the Atlantic cable of Fig. 6, and are shown in Table I.

TABLE I

Frequency $= n$	Knots	e or i	Maximum volts per volt at sending end
5	0	1	1
5	135	0·5135	0·5924
5	270	0·1755	0·3510
5	405	0	0·2079
5	540	−0·0616	0·1231
5	675	−0·0630	0·0729
5	810	−0·0432	0·0432
5	945	−0·0222	0·0256
5	1,080	−0·0076	0·0152
5	1,215	0	0·0090
5	1,350	0·0027	0·0053
5	1,485	0·0027	0·0031
5	1,620	0·0019	0·0019

These relations are shown graphically in Fig. 8. It is seen from the table that the maximum voltage impressed upon the cable has decreased to $\frac{1}{500}$ of its original value in one complete wavelength, and to 0.5924 of the original value in the first 135 knots from the transmitting end of the cable.

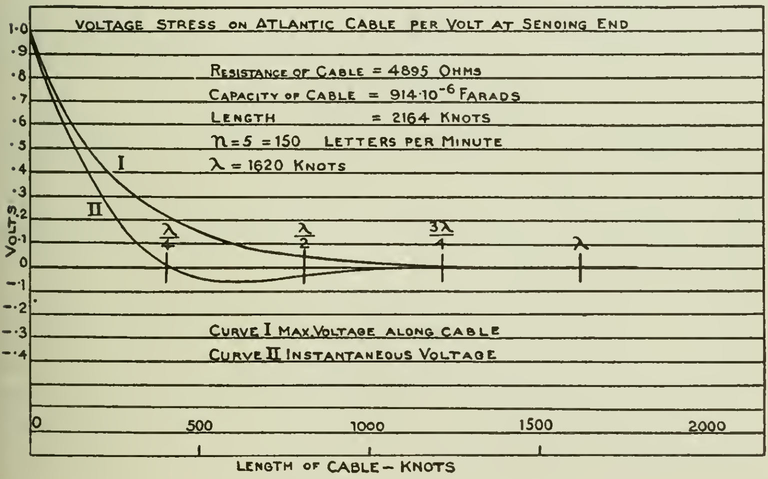
At this speed of signalling a complete wave is 1620 knots in length; also we have

$$\lambda = 1620 \text{ knots}$$

$$T = \frac{1}{n} = \frac{1}{5} \text{ second}$$

$$\text{Total length of cable} = 1.33\lambda.$$

FIG. 8.



Voltage stress on transatlantic cable for n=5, or 150 letters per minute.

Rate of propagation of wave through the cable $= \frac{\lambda}{T} = 8100$ knots per second, or the time required for the wave to travel the length of the cable = 0.27 of a second.

The frequency n has a marked influence upon the rate at which the amplitude of the wave decreases as we proceed along the cable from the transmitting end. The distance at which this amplitude will have $\frac{1}{\epsilon}$ of its original value is the reciprocal of the coefficient of x in the exponential term of (1), or

$$x' = \sqrt{\frac{2}{CR\omega}} = 258 \text{ knots}$$

or x' varies inversely with the square root of the frequency. This means that if we increase the speed of signalling from $n = 4$ to $n = 9$ the higher frequency wave will experience the same decrease in voltage in two-thirds of the distance from the transmitting end. In other words, the higher the speed of signalling attained on any cable for a given transmitting voltage, the safer the cable is from electrical strain. Increase in efficiency of the cable plant means increase in safety also.

With a battery, it is possible to subject every centimetre of the cable to the full voltage stress of the battery, as occurs whenever the usual insulation resistance test of the cable is made, or in case the transmitting condenser should be accidentally short-circuited.

With the alternating-current dynamo, however, it is impossible either by accident or by design to produce in the cable in the deep sea portion any voltage, even momentarily, of more than a small fraction of the voltage used at the transmitting end.

This suggests, as has been done before, that, by designing submarine cables with heavier insulation over comparatively short distances at the ends we can employ higher voltages in signalling with no possibility of subjecting the cable to undue electrical strain at any point of its length.

Submarine cables during manufacture are at present subjected to a stress of several thousand volts in the cable tanks for a considerable period, and if there is a material advantage in speed in increasing the signalling voltage there would seem to be no good reason for hesitating in the slightest degree to increase the voltage moderately in actual traffic.

Receiving Conditions.

In a long cable there is no reactive influence upon an ammeter or voltmeter placed in any circuit at the transmitting end due to any variation in the form of apparatus inserted at the receiving end of the cable. Opening and closing the cable circuit produces no perceptible indication. The energy of the waves may be considered as leaving the transmitting end of the cable along the conductor path never to return.

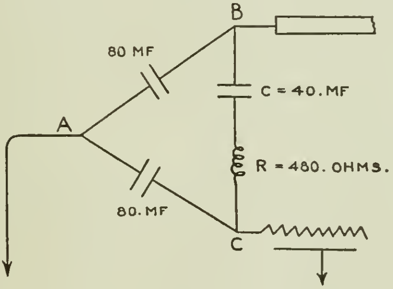
We are, therefore, at liberty to consider the electrical conditions for best receiving, separately and independently of the conditions for sending, and then inquire how far these two sets of conditions can be made to harmonize with each other.

Fig. 9 shows one of the standard arrangements for operating on long cables in which the values of the condensers and the resistance of the recorder coil as shown have become more or less fixed quantities in cable practice. The condenser c is limited to this comparatively small value, as its main function is to improve the definition of letters like " s " and " h," for there is no need to correct for letters like " a " and " n."

This lack of uniform resolving power for all letters at present limits the free use of any value of condenser in this arm which would be the most suitable from electrical considerations to increase the value of an alternating current in the recorder coil.

In Fig. 9 the attenuated alternating current at the receiving end of the cable is divided at the point B of the duplex bridge, and again subdivided at A and C inversely as the vector impedances of the paths.

FIG. 9.



Form of duplex circuit used on long cables.

In the recorder arm BC the ideal electrical conditions would be to so assign values to the receiving condenser c, and the inductance and resistance of the recorder coil, as to cause this arm of the bridge to be in resonance, entirely independently of the cable itself, the artificial line, or of any other arm of the bridge. In other words, we should so arrange matters if we could that if the arm BC is short-circuited on itself its natural frequency would be equal to the frequency of the current it is required to receive. In the abstract, there would be an infinite number of solutions for this arm, depending upon the stiffness function $\frac{L}{C}$ selected, each solution fulfilling the condition.

$$CL\omega^2 = 1.$$

The Cable Dynamo.

The alternator has been designed for the particular purpose of operating a cable, and possesses some novel features. Since we cannot reduce the number of poles to less than two, we must rely on a high magnetomotive force, and a minimum clearance for the armature to produce, at such low frequencies, the voltage required.

In addition, it is especially desirable to generate an accurate sine wave of E.M.F. These objects have been satisfactorily obtained in the design of the machine used in these experiments.

The resistance of each of the field coils is nearly 1000 ohms, and the inductance of the armature largely controls the current in the armature circuit, so that the machine can be short-circuited at full voltage without harm.

In starting and stopping the dynamo no form of switch is used, but, instead, the motor which operates the dynamo, starting from rest, gradually builds up the E.M.F. from zero, which gradually dies down to zero at stopping. In this manner there is never any possibility of a " break " in any metallic circuit connected with the transmitting apparatus.

Since the dynamo transmitter comprises the power plant for an ocean cable, it must, therefore, take its place on the instrument table, where the transmitter is directly geared to it. The armature is mounted on ball bearings, and runs with remarkable silence and smoothness under load.

The developments of wireless telegraphy have introduced alternating-current dynamos of considerable power of 100,000 and even 200,000 cycles per second; but for the present purpose we require an alternator to operate at from 4 to 10 cycles per second, and to develop 100 volts or more. This type of dynamo possesses some interest to the engineer, because it may be said to represent the extreme infra-red end of the dynamo spectrum, just as the high-frequency machines mentioned above represent the ultra-violet end. It would be strange indeed if the needs of telegraphy should be ultimately responsible for the development of both ends of this spectrum.

IV. *Summary.*

In the phenomenal development of the wireless art many instruments and methods have been imported from the much older art of wire telegraphy. In like manner may we not, to advantage, re-import some of the methods and instruments developed in wireless telegraphy into the art and science of cable telegraphy?

It has been truly said that "we begin to understand a phenomenon when we can measure it," and for this reason alone the present plan, it is thought, will appeal to physicists and engineers.

It is seen that once we can employ a system of signalling in which we are dealing with one fundamental frequency only, and the circuit is never broken, the process of measuring the constants of the cable itself and the most suitable bridge arrangements for high efficiency is greatly simplified.

The removal of any form of arc or spark from the cable circuit has been shown to very materially increase the accuracy of balancing the duplex bridge, while the smooth type of waves employed in sending the signals has enabled this important object to be attained with an accuracy greater than has been possible before.

Using the low-resistance coil of a transformer or autotransformer as the actual source of E.M.F. in the circuit comprising the cable itself enables each end of the cable to be permanently connected to earth, thus providing a drainage path for earth currents of all kinds induced in the cable, and also adding to its safety.

The present forms of cable recorders, relays and amplifiers, when relieved from the necessity of recording consecutive impulses in the same direction, are liberated from some practical restrictions which have heretofore hampered them.

In the example shown the recorder coil of the gold-wire relay oscillates back and forth at a definite frequency, and the inertia of the moving parts is, therefore, less troublesome, and we are at liberty to increase the flux of the magnetic field as well as reduce the control of the coil so as to allow it to vibrate more freely at its natural frequency.

No mention has been made of the possible application of this method of transmission to landlines, but it may be remarked that in the present Wheatstone automatic system there is great trouble caused by the induction of one line upon another, and if we could remove from the Wheatstone system the necessity of making and breaking the battery circuit at comparatively high voltage we could, at a single stroke, very largely reduce all such inductive effects.

The more usual method of developing a system of telegraphy is what might be called the "synthetical method"—that is, having certain fundamental principles which are proved to be correct, to endeavor to build up a system in practice which will possess as many as possible of these principles.

This method was employed in the earlier stages of these experiments, but it was only after abandoning this course altogether, and starting with the ideal solution as outlined above, that it was possible to proceed without radical compromise. It is known, for instance, that certain characteristics are very desirable in any cable system, such as

(*a*) All signals should represent equal lengths of time;

(*b*) No two consecutive signals should be of the same sign;

(*c*) The resolving power or definition of each letter of the alphabet should be as nearly as possible the same;

(*d*) The total quantity of electricity measured in coulombs impressed upon the cable should be as nearly as possible equal to zero for any two consecutive signals.

It will be seen, however, that the ideal solution for power transmission automatically comprises each of these conditions, and, in addition, has other advantages in safety to the cable property from undue electrical strain throughout every centimetre of its length.

The Vapor Pressure of Ethane and Ethylene at Temperatures Below Their Normal Boiling-points. G. A. BURRELL and I. W. ROBERTSON. (*The Journal of the American Chemical Society,* vol. xxxvii, No. 8, August, 1915.)—The authors of this report have needed at various times in working on the condensation of the constituents in natural gas and in studying the separation of gas mixtures by fractionally distilling them certain vapor-pressure measurements of gases at low temperatures. These have not been determined in the case of ethylene and only for a limited range (20° below the normal boiling-point) in the case of ethane. Hence in this paper are shown observations from 760 mm. down to 1 mm. Vapor pressures of propane, propylene, N-butane, iso-butane, butylene, and acetylene will follow in subsequent articles.

Saturated vapor pressures for ethane and ethylene at low temperatures are shown. In the case of ethane, the vapor pressures range from 760 mm. at – 89.3° to 1 mm. at – 159.8°. In the case of ethylene, the vapor pressures range from 760 mm. at – 103.9° to 4 mm. at – 159.9°.

The authors' experience with a bath devised by Henning for maintaining a constant low temperature is described.

THE PHYSICAL PHOTOMETER IN THEORY AND PRACTICE.*

BY

W. W. COBLENTZ, Ph.D.,
Associate Physicist, Bureau of Standards.

I.

It is well known that the photometry of light sources which are different in color is subject to great errors. In order to obviate this difficulty some form of radiometer which, unlike the eye, functions independently of the frequency (wave-length) and the intensity of the stimulus, has been advocated.

A bolometer or a thermopile is the simplest radiometer now available. In order to make it conform with the behavior of the average normal eye when subjected to a stimulus which does not deviate much from a certain specified intensity, it is necessary to interpose between the radiometer and the source of light (which is to be tested) an absorption screen which is opaque to all the infra-red and ultraviolet radiations and which transmits the visible radiations in proportion to the luminosity curve of the average normal eye. In other words, the spectral transmission curve of the absorbing medium must be an exact copy of the luminosity curve of the average normal eye, when subjected to a stimulus of a given intensity.

All this sounds very enticing in theory, but in practice the radiometer has various limitations which, as will be shown presently, may restrict its use to special problems which can be investigated at leisure, when conditions are favorable for operating the radiometric outfit.

This paper makes no pretence in giving the details of the development of the aforementioned ideas. In the earliest work by Féry[1] an absorption cell containing a solution of copper acetate was used, and no attempt was made to have its transmission curve coincide with the luminosity curve. Recently Karrer[2] has made a series of radiant luminous efficiency measurements on various light sources by determining the ratio of energy

---

* Communicated by the Author.

[1] Féry, *Bull. Soc. Franç. Physique*, p. 148, 1908.

[2] Karrer, *Physical Review*, 5, p. 189, 1915.

transmitted by the luminosity curve solution to the total energy radiated. The solution used by Karrer has been modified, and the one now recommended[3] has the following composition:

Cupric chloride	60.0 gr.
Potassium chromate	1.7 gr.
Cobalt ammonium sulphate	7.5 gr.
Nitric acid, sp. gr. 1.05	15.0 Cc.

Water to one litre of solution.

This solution is to be used in a parallel-walled glass tank 1 centimetre in thickness, but, as will be shown presently, this is not a sufficient thickness to be entirely opaque to infra radiations.[4] Fortunately the solutions used by Karrer were in separate tanks, forming a total thickness of 4.2 cm., which, as will be shown on a subsequent page, is sufficient to eliminate all the infra-red.

The question of the mechanical valuation of visible radiation, "light," by using a radiometer and an absorbing screen whose transmission curve coincides with the luminosity curve of the eye has been discussed by Houstoun,[5] Ives and others. Ives[6] has recently discussed the subject of physical photometry, and in his instrument the visual luminosity medium is complete in one solution. Unfortunately no mention is made of the thickness of the cell, which, from the printed illustration, appears to be 1 cm. in thickness.

The present inquiry into the merits of the physical photometer came about quite accidentally in connection with the question of the photometric determination of the transmission of a yellow and a blue solution for the luminous radiations from a "4-watt" carbon lamp. The yellow solution consists of 72 grammes of potassium dichromate per litre, and the blue solution contains 53 grammes of copper sulphate per litre; these being the concentrations specified by Ives and Kingsbury[7] to give the same transmission (for the light from a "4-watt" carbon lamp) as determined with a "physical photometer" (to be described shortly), which presumably employed the aforementioned luminosity solution.

---

[3] Ives, Coblentz, Kingsbury, *Phys. Review* 5, p. 269, 1915.

[4] The concentration of cupric chloride in the aforementioned luminosity solution amounts to only about 3 per cent. for a 2 cm. thickness. (Beer's law. Thickness and concentration are interchangeable.) In a previous paper (*Bull. Bur. Standards,* 9, p. 110, 1912) I have shown that a 3 per cent. solution is not sufficient to absorb all of the infra-red spectrum.

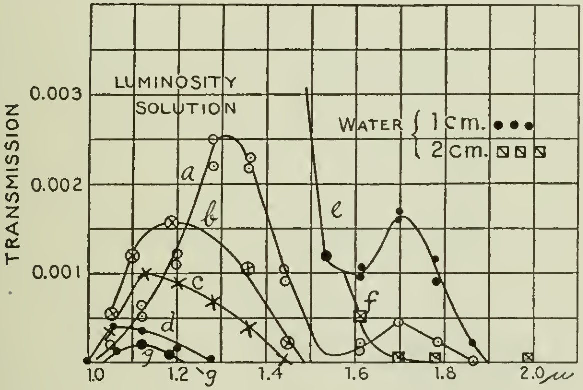
[5] Houstoun, *Proc. Roy. Soc. A,* p. 275, 1911.

[6] Ives, *Trans. Illum. Eng. Soc.,* 10, p. 101, 1915.

[7] Ives and Kingsbury, *Trans. Illum. Eng. Soc.,* 10, p. 203, 1915.

The copper sulphate solution is opaque to radiations beyond 0.9μ, and the dichromate solution is opaque beyond 1.4μ. Consequently the copper sulphate solution will absorb most of the radiations transmitted (at 1.2μ) by the luminosity curve solution; but they will not be absorbed by the dichromate solution. Hence, in making up a copper sulphate solution to give the same radiometric transmission as that given by the dichromate solution, the sulphate solution is to be expected to be the more transparent when measured radiometrically by means of a physical photometer employing a luminosity curve solution which is (as it should be) entirely opaque to infra-red radiations.

FIG. 1.

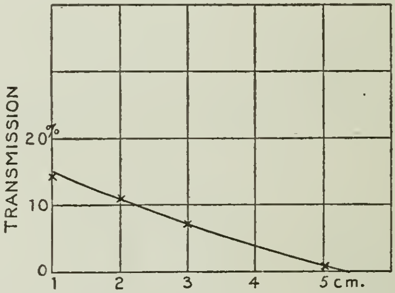


Showing the region of transparency in the spectrum of the luminosity curve solution.

In order to determine the validity of this surmise, the spectral transmission of these various solutions was determined by means of a fluorite prism and the spectro-radiometric apparatus used in various researches previously published. The galvanometer was steady to 0.1 mm. The Nernst glower used gave from 200 to 300 cm. deflection, so that it was an easy matter to make observations to 2 parts in 30,000 in the spectral region of 1μ to 2μ. The luminosity curve solution was found more transparent (Fig. 1, curve *a*) than anticipated, for a 1-cm. layer, and the greatest surprise was the observation of an additional transparent region at 1.7μ. This band is found in pure water (*i.e.*, it is not caused by the coloring matter in solution), and is not entirely eliminated in a 1-cm. layer. This is shown more clearly in an examination of pure water, curves *e* and *f*, Fig. 1, where this transparent region is entirely eliminated (curve *f*) in the 2-cm. layer of water.

The depression in the left-hand side of curve *a*, Fig. 1, was verified on a subsequent examination, from which it would appear that Beers's law (which states that the thickness and concentration are interchangeable) may not hold for highly-concentrated solutions. Curve *a* is entirely different from the transmission curves of cupric chloride previously published. Curve *b*, which gives the transmission of the luminosity solution diluted one-half and examined in a 2-cm. layer (hence equivalent to a 3 per cent. solution), agrees exactly with the data of a 3 per cent. solution of cupric chloride previously published.[8] Curves *c* and *d*, Fig. 1, give the transmissions of the above-mentioned luminosity solution diluted to one-third and one-fifth of its concentration, and examined in layers 3 and 5 cm., respectively, in thickness. This was done in order to determine what thickness of water (solution) would be necessary to eliminate the transparent band at 1.2μ in the luminosity curve solution. This could be accomplished by using a greater concentration of cupric chloride, but this would necessitate working out a new luminosity curve solution. Using a cell 5 cm. in thickness, and a concentration of

FIG. 2.



Showing the percentage of infra-red radiations as compared with the luminous radiations from a "4-watt" carbon lamp which are transmitted by a layer of luminosity curve radiation, 1, 2, 3, etc., centimetres in thickness.

---

[8] Coblentz, *Bull. Bur. Standards*, 9, p. 110, 1912.

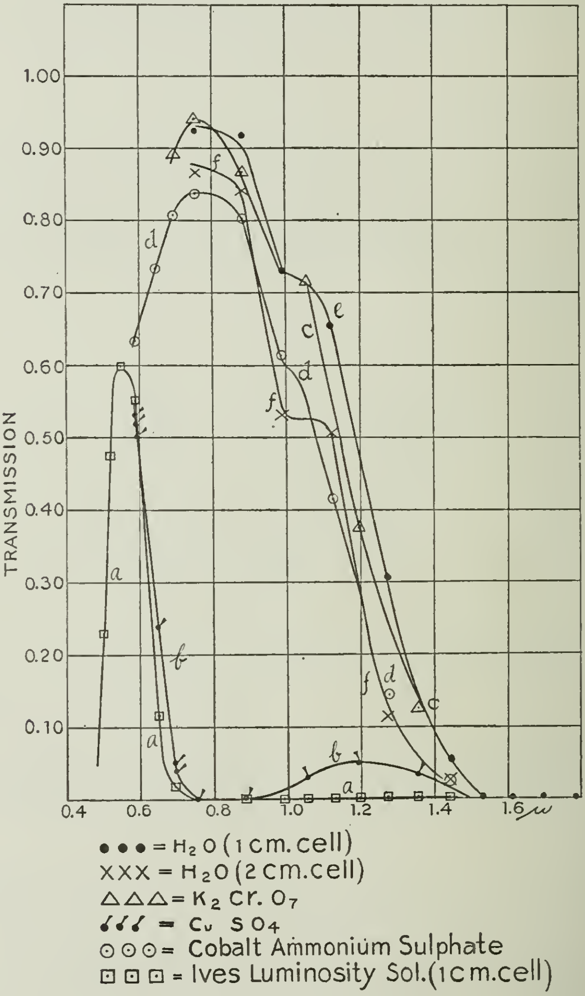
one-fifth of the prescribed ingredients of the above-mentioned luminosity curve solution, the amount of infra-red is from 0.6 to 0.8 per cent. of the visible radiations transmitted from a "4-watt" lamp. However, before using this solution it will be necessary to determine first whether the transmission curve has been appreciably modified, in the visible spectrum, by diluting the standard solution to one-fifth and then using it in a 5-cm. layer, instead of 1 cm. as prescribed.

In Fig. 2 are given the percentages of infra-red radiations as compared with the visible radiations from a "4-watt" carbon lamp, which are transmitted by a layer of luminosity curve solution, 1, 2, etc., centimetres in thickness, but diluted as described. These data were obtained by integrating the spectral energy curves of a "4-watt" lamp.

In view of the fact that the luminosity solution, when diluted, became more transparent than was expected, at 1 to 1.2μ, an examination was made to determine what thickness of pure water when used, in a separate cell, with the original concentration of luminosity curve solution (used in a cell 1 cm. in thickness), would eliminate the transparent band at 1.3μ. As shown in curve *g,* Fig. 1, the combination of a cell of pure water, 3 cm. in thickness, with a cell of the undiluted luminosity curve solution, 1 cm. in thickness (the two cells forming an absorbing layer 4 cm. in thickness), is far more opaque at 1.2μ than is the 5-cm. layer of diluted luminosity solution. This is due to the great opacity of the luminosity curve solution at 1.1μ. In practice, however, it seems desirable to use a cell of water 4 cm. in thickness, combined with a cell 1 cm. in thickness containing the luminosity curve solution in its full concentration as originally prescribed. This should insure the elimination of all infra-red radiations.

In Fig. 3 are given the transmission curves of various substances discussed in this paper, the cells being 1 cm. in thickness. Curve *a* shows the transmission through the undiluted luminosity curve solution, the region at 1 to 2μ being plotted to a larger scale in Fig. 1. Curve *b* gives the transmission of copper sulphate (53 grammes per litre); and curve *c* gives the transmission of potassium dichromate (72 grammes per litre) mentioned on a previous page. The transmission of cobalt ammonium sulphate (6 gr. in 94 Cc. of water; 6 per cent. solution) is given in curve *d*. Curves *e* and *f* give the transmissions of pure water in layers 1 and 2 cm., respectively, in thickness. It is to be noted that the potassium dichromate and the cobalt ammonium sulphate solutions are almost as transparent as pure water, in marked contrast with the solutions of copper salts.

FIG. 3.



Transmission of various solutions.

The numerical values of the transmissions of the various solutions and of pure water are given in Table I.

TABLE I

Transmission of Various Solutions.

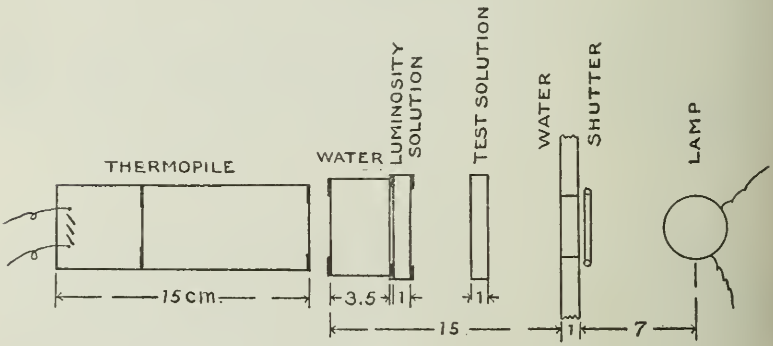
Wave-length	Luminosity curve solution					Water		Copper sulphate	Potassium dichromate	Cobalt ammonium sulphate
μ =0.001 mm.	Undiluted. Cell 1 cm.	Diluted to ½. Cell 2 cm.	Diluted to ⅓. Cell 3 cm.	Diluted to ⅕. Cel 5 cm.	Cell 1 cm. + Water Cell 3 cm.	Cell 1 cm.	Cell 2 cm.	Cell 1 cm.	Cell 1 cm.	Cell 1 cm.
.882μ	......	......	......	......	......	.912	.842	.0016	.871	.802
.991	.00000	.00000	......	.00010	......	.731	.530	......	.....	.615
1.054	.00026	.00045	.00045	.00044	.00015	......	......	.031	.715	.....
1.123	.00058	.00115	.00105	.00043	.00022	.656	.507	......	.....	.415
1.197	.0012	.00157	.00085	.00022	.00015	......	......	.050	.376	.....
1.276	.0023	......	.00074	.00014	.00006	.308	.113	......	.....	.147
1.357	.0021	.00105	.00036	.00006	.00001	......	......	.031	.124	.....
1.441	.00092	.00015	.00008	.00000	......	.0525	.0259	......	.....	.0225
1.526	......	.00003	.00000	......	......	.00123	......	......	.....	.....
1.613	.00019	.00000	......	......	.00000	.00098	.00005	.0005	.0013	.00074
1.698	.00047	.00004	......	......	.00000	.00170	.00000	.0008	.0020	.00101
1.784	.00027	.00000	......	......	......	.00113	.00000	.0005	.0013	.00082
1.869	.00000	......	......	......	......	.00024	......	......	.....	.....

II.

Experiments with a Precision Physical Photometer.—Having worked out the details for entirely eliminating the infra-red radiations from the radiometer, it was of interest to make some practical tests upon objects for which the instrument seemed adapted. Because of the lack of sensitivity of the radiometer, as compared with the eye, this device cannot measure very small variations in luminous intensity, unless a very sensitive galvanometer can be employed. However, for standardizing colored solutions which are to be used as transmission screens in physiological, psychological, and photometrical investigations, the physical photometer appears to have an important field. Further investigation of the instrument will, of course, be necessary, especially the luminosity curve solution, the temperature coefficient of transmission of which must be determined.

The physical photometer, as used in the present work, is a very simple device, consisting of a surface (or linear) thermopile of bismuth-silver, at a short distance of about 15 cm. in front of which was placed the luminosity curve solution and water cell. The lamp stood at a distance of about 20 cm. from the water cell, and in the intervening space stood a water-cooled diaphragm and shutter, as shown in Fig. 4. The bismuth-silver thermopiles used have been described elsewhere.[9] The design and behavior of the surface thermopile used in this work have been described recently.[10] The auxiliary galvanometer used is the newly-designed ironclad instrument [11] in which the magnetic perturbations have been eliminated. This is more important than the question of sensitivity, which in the present work was $i = 5 \times 10^{-10}$ ampère for a single swing of 2 seconds. In view of the fact that the luminosity curve solution becomes warmed by absorbing most of the radiations from the lamp, and causes a drift of the galvanometer reading by radiating upon the thermopile, the ballistic throw of the galvanometer was used. This throw is known to be proportional to the final steady deflection, and could be measured in 2 seconds. It was therefore possible to make a radiometric measurement in 5 to 6 seconds.

Fig. 4.



Showing the arrangement of the physical photometer.

The Transmission of Solutions.—The first tests were made on the "blue" (copper sulphate) and the "yellow" (potassium dichromate) solutions mentioned on a previous page, and, in view of the fact that it is desirable to illustrate the precision attained, the data are given *in extenso*. The first trial was with linear thermopile No. 53 and a cell 1 cm. in thickness, containing the luminosity curve solution at 28° C. The source was a "4-watt" carbon lamp. As already stated, the 1-cm. solution transmits 13.6 per cent. of the infra-red radiations from the "4-watt" lamp. Of the 13.6 per cent. infra-red transmitted by the luminosity curve solution, 19.5 per cent. is transmitted by the yellow solution and 3.7 per cent. is transmitted by the blue solution. In both cases erroneous results must occur in attempting to determine their transmission for luminous radiations, when using the 1-cm. cell of luminosity solution. This fact is demonstrated by taking the ratios of the transmissions $\frac{\text{blue}}{\text{yellow}}$. A series of seven measurements (July 26, ratio $B:Y = 1.021$, 036, 020, 032, 031, 013, 027) gave a mean value of $B:Y = 1.026$. Repeating the work with a surface thermopile (July 30, $B:Y = 1.018$, 020) gave a mean value of $B:Y = 1.019$.

---

[9] This Journal, 172, p. 559, 1911; *Bull. Bur. Standards,* 11, p. 132, 1914.

[10] *Phys. Rev.* (2), 5, p. 269, 1915.

[11] *Bull. Bur. Standards,* 9, p. 61, 1912; 11, p. 180, 1914.

A layer of water 1 cm. in thickness, used in addition to the 1 cm. luminosity solution, removes part of the infra-red transmitted by this solution, and thus reduces the amount transmitted by the yellow (and blue) solutions. The ratio of $B:Y$ should therefore be larger than the one just determined. A series of six measurement (July 26, linear thermopile, ratios $B:V = 1.055$, 040, 048, 030, 042, 044) gave a mean value of $B:Y = 1.043$, which larger value was to be expected.

Using only the 1-cm. cell of luminosity solution, the transmission of the yellow solution was 0.547. Correcting this value by 13.6 per cent. for the infra-red which is transmitted by the luminosity solution, the true transmission (at 29° C.) of the yellow solution, for the *visual* radiations from a "4-watt" carbon lamp, is 0.622, which, as will be noticed presently, is in remarkably close agreement with the value obtained by using a luminosity solution which transmits no infra-red radiations. This close agreement is to be emphasized because the correction factor of 13.6 per cent, was obtained (by integrating the part of the spectral energy curve of the "4-watt" lamp) before the luminosity curve solution and water-cell combination, for eliminating all the infra-red, had been developed.

The crucial test of these transmissions was made with a surface thermopile No. 46, and the combination of a 1-cm. cell of luminosity curve solution and 3.5 centimetres of water. The water happened to be in two cells, 1 and 2.5 cm., respectively, in thickness, the luminosity solution cell being between them. Black paper diaphragms, with holes smaller than the inside diameter of the glass walls of the cells, prevented reflections. To prevent reflections from the intervening glass windows, in one series of measurements ("August 4," to be mentioned presently) these cells were joined with glycerine. However, there is no difference in the results. A series of ten measurements (August 3, temperature 29°, ratio $B:Y = 1.085$, 085, 095, 080, 079; August 4, $B:Y = 1.083$, 079, 083, 077, 082) gave a mean value of $B:Y = 1.083$. In other words, the blue solution transmits over 8 per cent. more visible radiations ("light") from the "4-watt" carbon lamp than does the yellow solution. As stated in the beginning of this paper, if blue and yellow solutions are made up to give equal transmissions, for a "4-watt" lamp, as determined radiometrically, using only the 1-cm. layer of luminosity solution which transmits 13.6 per cent. of the infra-red radiations of this lamp, then the blue solution must be the more transparent when tested with a luminosity curve solution which transmits no infra-red radiations.

The transmission of these solutions for the visible radiation from a "4-watt" lamp was determined radiometrically, using the aforementioned combination of 1 cm. of luminosity curve solution and 3.5 cm. of water, which eliminates all of the infra-red. A series of nine measurements (August 3, 0.623, 0.629, 0.620, 0.616; August 4, 0.620, 0.617, 0.623, 0.624, 0.622) gave a mean value of 0.621 for the transmission of the yellow solution; and from this, using the ratio of $B:Y = 1.083$, the transmission of the blue solution is 0.673. In other words, the yellow solution transmits 62.1 per cent. and the blue solution transmits 67.3 per cent. of the "light"—the visible radiations from a "4-watt" carbon lamp. These two solutions, in their cells, were loaned to me by my colleagues, Messrs. Crittenden and Richtmyer, who are investigating them photometrically. It will therefore be of interest to await their results. As already mentioned, it will be necessary to determine the temperature coefficient of transmission for the different wave-lengths transmitted by the luminosity curve solution. Unless the unusually close agreement between the photometric and radiometric measurements on a standard lamp, to be described presently, are merely fortuitous, it would appear that the temperature coefficient is of minor importance.

Determinations of transmission of the yelow solution and of the ratio blue to yellow were made with the luminosity solution diluted to one-fifth and used in a 5-cm. cell. The mean value of 12 closely agreeing determinations of the transmission of the yellow solution was 0.624, which is in agreement with the above-mentioned measurements, viz., 0.621. There is one inconsistency in that the ratio of the blue to yellow is 1.001. This can be explained if the whole absorption band of the luminosity solution is shifted toward the visible spectrum, which would affect the blue solution. In view of the fact that the 5-centimetre cell of diluted luminosity curve solution is not perfectly opaque in the infra-red, and hence not perfectly satisfactory, it seemed unnecessary to pursue the investigation. As a question affecting " Beers's law " of the interchangeability of thickness and concentration of solution, it would be of interest to investigate the effect of change in concentration upon the transmission band of the luminosity curve solution.

Measurements on a Standard Incandescent Lamp.—In the foregoing tests all the measurements were made by one observer and his assistant. To eliminate all possible bias in the final results, and to make a thoroughly practical test of the physical photometer, measurements were on a vacuum tungsten lamp, kindly supplied by my colleagues, Messrs. Middlekauff and Skogland. This is one of a series of lamps, photometered by a group of observers, and the constants are accurately determined. The only data supplied me at the start were the currents on which the lamp was to be operated (see Table III).

In these radiometric measurements the combination of luminosity curve solution and 3.5 cells of water was used as already described. The currents were regulated by measuring the potential across a standard 1-ohm resistance, by means of a potentiometer. It was found that a change of 1 per cent. in the current changed the galvanometer (sensitivity $i = 5 \times 10^{-10}$ ampère) deflection 6 to 8 mm., so that a change of 0.1 per cent. in current made an appreciable change in the deflections, which usually could be read to 0.1 to 0.2 mm. The assistant therefore kept the current constant to 0.0001 ampère, and recorded the observations.

After changing the current in the lamp, it was often necessary to keep the shutter raised several minutes in order to establish temperature equilibrium between thermopile and the absorption cells before making observations.

Another difficulty encountered was that the operating currents through the lamp differed too much in magnitude, so that in taking ratios the galvanometer deflections differed considerably. The galvanometer being undamped on a 2-second swing, was not well adapted for this test. The ballistic throw is not proportional for very large deflections (12 to 15 cm.) as compared with small deflections, being too large when observing large deflections. This makes the ratios larger than the true value. This, of course, was known before making the observation, and such readings should therefore not have been included in determining the mean value. In Table II are given the ratios of the luminous intensities of the lamp for the different currents (say 0.3258 and 0.3108 ampère), the spacing of the horizontal lines indicating the order of observations. The value 1.356 is too high because of the large ballistic throw. The values 1.373 and 1.332 are poor sets, due to a sudden unsteadiness ("kicks") in the galvanometer, which occurs unexpectedly, at infrequent intervals, and which is supposed to be caused by radiotelegraphic disturbances.

Table II

Giving the Ratios of Luminous Intensities, as Determined with a Physical Photometer, for Different Currents (see Table III).

Ampères		
$\frac{.3258}{.3108}$	$\frac{.3404}{.3258}$	$\frac{.3542}{.3404}$
1.356 →	1.319	
	1.311	
←	1.311	
1.351		
1.344		
1.346 →	1.313	
	1.314	
	1.313 →	1.273
		1.280
		1.273
	←	1.274
1.373 }	Poor set.	
1.332 }		
1.337		
Mean values		
1.347	1.313	1.275

These ratios were tabulated and the results handed to Dr. Middlekauff, who then gave me the complete data recorded in Table III. The ratios of the luminous intensities (candle-powers) and the ratios of the intensities determined radiometrically are in surprisingly close agreement, especially when one considers that the radiometric measurements were made in three hours, while the photometric measurements involve many observers and weeks of intercomparison. In a total change of luminous intensity amounting to over 23 candle-power, the difference between the photometric and the radiometric determination is less than 0.2 per cent.

TABLE III

Showing the Constants of a Vacuum Tungsten Lamp, Determined Photometrically; and Radiometrically Using a Physical Photometer. In a Total Range of Luminous Intensity Amounting to 23 c.p. the Difference between the Photometric and the Radiometric Determination is only 0.2 per cent.

Volts	Ampères	Candle-power	Watts per candle	Ratio of candle-power (column 3)	Ratio of intensities determined with a physical photometer
96	.3108	18.21	1.628		
104	.3258	24.50	1.375	1.345	1.347
112	.3404	32.28	1.174	1.316	1.313
120	.3542	41.03	1.030	1.271	7.275
			Ratio: 41.03÷18.21=2.252		2.256

The advantage of such a device as the physical photometer for measurements in heterochromatic photometry is apparent. One can compare lamps with the standards, regardless of color. However, the problem is not entirely solved, for further information must be obtained on the luminosity curve solution, as well as on the luminosity curve of the so-called average eye.

Summary.—This paper gives data showing that a given luminosity curve solution transmits 13.6 per cent. infra-red radiations from a "4-watt" carbon lamp, due to the fact that this solution has a region of considerable transparency at 1.0 to 1.3μ. Experiments are given showing that the concentration and the thickness of this solution are not interchangeable—at least not for the infra-red region at 1.2μ. In order, therefore, to eliminate all the infra-red, by means of water, it is therefore necessary to use the luminosity curve solution and the water in separate cells. A layer of water 4 cm. in thickness is recommended, to be used with the 1-cm. layer of luminosity curve solution, in order to entirely absorb the infra-red spectrum.

A precision physical photometer is described, consisting of a thermopile in front of which is placed the above-mentioned combination of luminosity curve solution and water cell. Practical tests are made with this instrument, including the measurement of the transmission of certain yellow and blue solutions for the visible radiations from a "4-watt" carbon lamp. Precise measurements were made on ratios of luminous intensities of a standardized vacuum tungsten lamp, and the radiometric measurements were found in agreement within 0.2 per cent. with the photometric measurements.

In addition to the gentlemen mentioned in the text, especial acknowledgment is due my assistant, Mr. W. B. Emerson, for assisting in this work.

Washington, D. C., August 6, 1915.

Since writing the above paper, Dr. Ives has called my attention to his latest recommendations (in the *Trans. Illum. Eng. Soc.*, 10, p. 315, 1915) relative to the use of the physical photometer.

The luminosity curve solution given above has been modified, so that its transmission curve more nearly approximates the color sensibility curve of the average eye.

The concentrations now recommended are:

Cupric chloride	60.0 grammes
Potassium chromate	1.9 grammes
Cobalt ammonium sulphate	14.5 grammes
Nitric acid (1.05 gr.)	18.0 c.c.
Water to	1 litre

This solution, which is to be used in a cell 1 centimetre in thickness, is to be protected from overheating by the interposition of a layer of clear water at least 2 cm. in thickness.

As mentioned in the text, a cell of clear water not less than 4 cm. in thickness is necessary in order to render this absorption screen entirely opaque to all the infra-red.

In conclusion, it is desirable to call attention to the fact that the data on the "Mechanical Equivalent of Light" (Ives, Coblentz and Kingsbury), *Phys. Rev.*, 5, p. 269, 1915) which relate to the measurements with the luminosity solution and the "4-watt" lamp must be corrected by 13.6 per cent., because of infra-red transmitted by the luminosity curve solution. In a forthcoming paper by the writer on the coefficient of total radiation of a black body, data will be given which place the value of this constant at $\sigma = 5.74 \times 10^{-12}$ watts per cm.^{2} per deg.^{4} This is the same as the value $(5.7 \times 10^{1-2})$ used in calibrating the lamp standards employed in the above measurement of the mechanical equivalent of light. There is therefore no correction to the lamp standard used in calibrating the thermopile, excepting a possible correction of perhaps 1 or 2 per cent. for atmospheric absorption by water vapor. This, however, is a greater refinement than the original data admit. The investigation of the mechanical equivalent of light must, of course, be undertaken anew, in view of the experience gained and the improved facilities now available.

August 9, 1915. W. W. C.

ON THE FACTOR TO BE USED FOR THE CALCULATION OF THE PHOSPHORIC ACID IN NEUMANN'S METHOD.

THE FACTOR AS INFLUENCED BY THE WATER USED FOR WASHING THE YELLOW PRECIPITATE.[1]

BY

S. L. JODIDI, Ph.D.,

AND

E. H. KELLOGG, B.S.

Office of Plant Physiological and Fermentation Investigations, Bureau of Plant
Industry, U. S. Department of Agriculture.

INTRODUCTION.

In our investigation into the chestnut bark disease caused by a fungus parasite known as *Endothia parasitica,* and more especially in our study of the metabolism of the chestnut bark under physiological and pathological conditions, it was deemed advisable, among other things, to ascertain the phosphorus content of healthy and infected chestnut bark. A preliminary examination showed both of them to contain but a small proportion of phosphorus. This suggested the use of an accurate method which, because of the considerable number of bark samples to be analyzed, had also to be expeditious. Owing to the important rôle the phosphoric acid plays both in the organic and inorganic world, many methods, gravimetric, volumetric,[2] acidimetric,[3] iodometric,[4] colorimetric,[5] have been devised for its estimation. While the gravimetric[6] methods are undoubtedly the most accurate known, they have the disadvantage in that they require for their execution more time and larger quantities of material than the volumetric methods do.

---

[1] Read at the meeting of the American Chemical Society, New Orleans, March 31 to April 3, 1915, and published by permission of the U. S. Secretary of Agriculture.

[2] *Z. anal. Chem.,* 9, 203 (1870); *Bull. soc. chim.,* 50, 353 (1888); *Compt. rend.,* 93, 495 (1881); *Jahresber. Chem.,* Liebig u. Kopp, 1853, 642; *Arch. wiss. Heilk.,* 4, 228; *J. prakt. Chem.,* 76, 104 (1859).

[3] Hundeshagen, *Z. anal. Chem.,* 28, 171 (1889); Thilo, *Chemiker Z.,* 11, 193 (1887); Manby, *J. Anal. Appl. Chem.,* 6, 82 (1892); Handy, *Ibid.,* 6, 204 (1892); Pemberton, *Jour. Amer. Chem. Soc.,* 15, 382 (1893).

[4] *Z. anal. Chem.,* 20, 507 (1881); *Ber.,* 28, 2061 (1895); *Z. anal. Chem.,* 36, 81 (1897); *Z. landw. Versuchsw.,* 17, 92 (1914).

[5] *Bull. soc. chim. Paris,* 47, 745 (1887); *Pharm. Centralbl.,* 35, 170 (1894); *Chem. Centralbl.,* 68, 126 (1897); *Jour. Amer. Chem. Soc.,* 23, 96 (1901); 25, 169 (1903); 25, 1056 (1903); 26, 808 (1904); 26, 1463 (1904); 27, 121 (1905).

[6] Fresenius, "Quant. Analys.," 6th edition, vol. i, 402 (1903); Treadwell, "Analyt. Chemistry," 3d edition, vol. ii, p. 434 (1914).

Of the considerable number of acidimetric methods described, many of which are based on the titration of the ammonium phospho-molybdate precipitate, the one presented by Neumann [7] seems to be quite generally in vogue. Not only is Neumann's method preferably employed in biological investigations for the determination of phosphoric acid in nucleic acids, lecithins, phosphatides, animal and plant tissues, etc., but in ores, steel, iron, phosphate rocks, and fertilizers just as well.

The Incorrectness of the Factor Employed in Neumann's Acidimetric Method.

Despite the fact that Neumann's method has been in use already for over ten years, it was only very recently that Heubner [8] and Wardlaw [9] have shown the factor 0.554—as proposed by Neumann and applied in his method for the calculation of phosphoric acid—to be incorrect. The experimental evidence presented by Heubner demonstrated that the above-mentioned factor, leading as it does to the not negligible error of about three per cent., is to be replaced by the factor 0.57, which is more nearly correct. From this it would seem that previous records in the literature of phosphoric acid estimations according to Neumann's method must have been too low. The latter method being of great practical value as well as of general interest, a solution of the question as to which of the two factors—Neumann's or Heubner's—is correct seemed to be desirable, if not imperative. Moreover, additional data, it was hoped, might help to clear up the discrepancy between the factor theoretically deduced by Neumann and the factor empirically secured by Heubner. Furthermore, this question had a specific interest for us, inasmuch as we had applied Neumann's acidimetric method to our work on the chestnut bark disease prior to the publication of Heubner on the factor to be applied in Neumann's method.

---

[7] A. Neumann, *Z. physiol. Chem.*, 37, 129 (1902–03); 43, 35 (1904–05); Gregersen, *Z. physiol. Chem.*, 53, 453 (1907); Bang, *Bioch. Z.*, 32, 443 (1911).

[8] *Biochem. Z.*, 64, 393 (1914).

[9] *Chemical Abstracts*, 8, 3540 (1914).

The Theory of Neumann's Method.

Neumann based his method on the fact that the yellow precipitate of ammonium phosphomolybdate obtained from a nitric acid solution under certain conditions has—as was demonstrated by the work of Hundeshagen[10]—the composition: 12 MoO_3, $(NH_4)_3PO_4$, 2 HNO_3. Taking into consideration that a sharp and exact titration of the yellow precipitate against standard alkali, with phenolphthalein as indicator, can be accomplished only after the ammonia has been removed, we obtain, on doubling the above formula, the following equation: 24 MoO_3, 2 $(NH_4)_3PO_4$, 4 $HNO_3 + 56\ NaOH = 24\ Na_2MoO_4 + 2\ Na_2HPO_4 + 4\ NaNO_3 + 32\ H_2O + (6\ NH_3)$. This means that 56 molecules of NaOH required to neutralize the yellow precipitate and to remove the ammonia correspond to 2 Na_2HP_4 (= 142 grs. P_2O_5). By using $\frac{n}{2}$ NaOH for titration we can express the above data as follows: 112 litres of $\frac{n}{2}$ NaOH = 142 grs. P_2O_5, hence 1 c.c. $\frac{n}{2}$ NaOH is equivalent to 0.554 milligramme P. It is this factor (0.554) that proved to be about three per cent. lower than the average factor (0.57) to which the work of Heubner has led.

Heubner's factor having been fully corroborated by the work of one[11] of us, as giving very nearly correct results under the conditions outlined in the paper, the question seemed of considerable interest as to what causes the deviation from the theoretical factor 0.554. Several reasons may be responsible for this difference. In the first place it has been stated in the literature by various investigators that the composition of the yellow precipitate may vary under different conditions of precipitation. Further, it is altogether not out of the question that in Neumann's method the ammonium phosphomolybdate is not absolutely insoluble in the liquid from which it is thrown down, in which case the filtrate from the yellow precipitate must still contain some phosphorus. Moreover, the yellow precipitate formed may, though to a small extent, be lost in the course of the various manipulations incident to that method. This may especially be due to the effect of the wash water on the yellow precipitate. It is with these questions that we shall chiefly be concerned in this paper.

---

[10] *Z. analyt. Chem.*, 28, 141 (1889).

[11] Jodidi, S. L., *Journ. Amer. Chem. Soc.*, 37, 1708 (1915).

Data Concerning the Solubility of the Ammonium Phosphomolybdate Precipitate in Water.

A review of the literature in question shows that there is considerable divergency of opinion as to whether or not the yellow precipitate is soluble in water. Hundeshagen,[12] who was one of the first to investigate into the nature of the ammonium phosphomolybdate precipitate with the object in view of elaborating a volumetric method for the estimation of phosphoric acid, is of the opinion that only ice-cold water should be used for the washing of the yellow precipitate, since in case water of room temperature is used it is hard to prevent traces of the precipitate from going through the filter or into the solution.

Pemberton [13] draws from his experiments the conclusion that there is no danger of loss in washing the yellow precipitate with water.

Isbert and Stutzer [14] hold that the ammonium phosphomolybdate is insoluble in cold water.

Eggertz [15] states that the solubility of the ammonium phosphomolybdate in pure water is 1 : 10,000, to which Hundeshagen remarks that in his experience the solubility is considerably greater.

Neumann [16] maintains that the yellow precipitate is altogether insoluble in the liquid in which it was thrown down, and is so difficultly soluble in very cold water that only a minute amount of it is dissolved after it has been in contact with the water for a long while.

Wardlaw [17] states that by evaporating down the washings extremely slight amounts of the precipitate were found to have dissolved.

Our observations made during the work reported in the first paper [18] of this series pointed to slight solubility of the ammonium phosphomolybdate in water. It seemed desirable quantitatively to ascertain just how much of the yellow precipitate is dissolved or otherwise lost in the course of the various manipulations.

---

[12] *Z. analyt. Chem.*, **28**, 164 (1889).

[13] *Journ. Amer. Chem. Soc.*, **15**, 386 (1893).

[14] *Z. analyt. Chem.*, **36**, 583 (1897).

[15] *Z. analyt. Chem.*, **28**, 161 (1889).

[16] *Z. physiol. Chem.*, **37**, 132 (1902–03).

[17] *Jour. Proc. Roy. Soc. New South Wales*, **48**, 83 (1914).

[18] *Jour. Amer. Chem. Soc.*, **37**, 1708 (1915).

In the washing of the yellow precipitate several factors are evidently involved; namely, the quantity of wash water applied, its temperature, the duration of its contact with the precipitate, which again in some measure depends upon the physical properties of the yellow precipitate as well as of the filter. While the operator has full control of the first two factors (quantity of wash water and its temperature), he is confronted with the fact that the last-named factors are more or less incidental.

EXPERIMENTAL.

For our experiments we have used the phosphates of sodium, potassium, and ammonium as well as the free phosphoric acid. The data obtained according to Neumann's acidimetric method were calculated to the results found by the usual gravimetric[19] method in which the phosphoric acid is precipitated as magnesium ammonium phosphate and weighed as pyrophosphate. Inasmuch as more recent work of Gooch,[20] Neubauer,[21] Järvinen,[22] Schmitz,[23] Jörgensen,[24] and others has demonstrated that when the phosphoric acid is precipitated in the cold it is quite difficult to obtain a pure precipitate of $MgNH_4PO_4$, which is, however, the case when the precipitation takes place in a hot solution, it was deemed necessary to check up all of the analyses made according to the gravimetric method as given in Fresenius by the newer method of Schmitz.[25] Both methods were further checked up by the conversion of the alkali orthophosphates into the corresponding pyrophosphates and metaphosphates respectively. In order to avoid errors due to imperfectly-graduated vessels, we have used throughout these experiments the same burette of 50 c.c. and the same flask of 250 c.c. which were found to be accurately graduated and to closely agree with each other. Further, we have used for each series of experiments the same stock solution, which was usually sufficiently dilute and kept in a well-stoppered flask. Whenever possible the portions of the solution to be analyzed were simultaneously measured out. Again, in order to exclude the influence of individual errors as much as possible it was deemed advisable to base the conclusions upon a considerable number of, in the most cases, concordant analyses, the average of which could be considered as reliable. The precipitation of the ammonium phosphomolybdate was accomplished exactly in the manner described in a previous paper.[26] When modifications were applied they will be mentioned.

---

[19] Fresenius, "Quantitative Anal.," 6th edition, 1, 402 (1903).

[20] *Z. anorg. Chem.*, 20, 135 (1899).

[21] *Z. angew. Chem.*, 1896, 439.

[22] *Z. anal. Chem.*, 43, 279 (1904); 44, 333 (1905).

[23] *Ibid.*, 45, 512 (1906).

[24] *Ibid.*, 45, 278 (1906).

[25] *Loc. cit.*

SERIES A.

Nine grammes of primary potassium phosphate (KH_2PO_4) were dissolved in water, the solution made up to about five litres and thoroughly shaken. Eight portions of this solution of 250 c.c. each were subjected to gravimetric analysis according to Fresenius's method, eight like portions according to Schmitz's method, while five portions of 50 c.c. each were converted into metaphosphate by ignition. The data obtained are summarized in the table below.

TABLE I.

Number of analysis	Found			Number of analysis	Found		
	(a) $Mg_2P_2O_7$ (Fresenius)	(b) $Mg_2P_2O_7$ (Schmitz)	(c) KPO_3		(a) $Mg_2P_2O_7$ (Fresenius)	(b) $Mg_2P_2O_7$ (Schmitz)	(c) KPO_3
	Gramme	*Gramme*	*Gramme*		*Gramme*	*Gramme*	*Gramme*
1......	0.3697	0.3697	0.0783	5......	0.3696	0.3672	0.0782
2......	0.3697	0.3688	0.0778	6......	0.3698	0.3679	......
3......	0.3689	0.3689	0.0785	7......	0.3699	0.3679	......
4......	0.3694	0.3677	0.0785	8......	0.3699	0.3682	......
Mean..	....	....	....	....	0.3696	0.3683	0.0783

Hence, 1 c.c. of the solution contains 0.41171 mg. P (*a*), or 0.41025 mg. P (*b*), or 0.41106 mg. P (*c*).

Titration According to Neumann's Method.

Thirty portions of the above solution of 25 c.c. each were subjected to titration by Neumann's method. It is a matter of course that all numbers of this as well as of the other series were treated exactly in the same manner, with the only difference that the quantities of water applied for washing the yellow precipitate varied with the different numbers. The data are presented in

---

[26] Jodidi, S. L., *Journ. Amer. Chem. Soc.*, 37, 1709 (1915).

Table II. The column of this table which gives $\frac{n}{2}$ NaOH used needs some explanation, which is also true of the corresponding tables of the other series. Gregersen[27] has pointed out that in Neumann's method carbon dioxide present in the liquids to be titrated is a source of error tending somewhat to increase the quantity of $\frac{n}{2}$ NaOH necessary for the neutralization of the ammonium phosphomolybdate.

TABLE II.

$\frac{n}{2}$ NaOH used C.c.	[28]Factor based on estimation of			$\frac{n}{2}$ NaOH used C.c.	Factor based on estimation of		
	(a) $Mg_2P_2O_7$ (Fresenius)	(b) $Mg_2P_2O_7$ (Schmitz)	(c) KPO_3		(a) $Mg_2P_2O_7$ (Fresenius)	(b) $Mg_2P_2O_7$ (Schmitz)	(c) KPO_3
17.83	0.577	0.575	0.576	18.10	0.569	0.567	0.568
17.73	0.581	0.579	0.580	17.80	0.578	0.576	0.577
17.53	0.587	0.585	0.586	18.10	0.569	0.567	0.568
17.85	0.577	0.575	0.576	17.75	0.580	0.578	0.579
17.73	0.581	0.579	0.580	18.35	0.561	0.559	0.560
17.95	0.573	0.571	0.573	17.75	0.580	0.578	0.579
18.00	0.572	0.570	0.571	.....	.....	.....	.....
17.90	0.575	0.573	0.574	.....	.....	.....	.....
	Mean of Nos. 1–8				Mean of Nos. 9–14		
17.81	0.578	0.576	0.577	17.97	0.573	0.571	0.572
17.93	0.574	0.572	0.573	18.30	0.562	0.560	0.562
17.90	0.575	0.573	0.574	18.10	0.569	0.567	0.568
17.80	0.578	0.576	0.577	18.17	0.566	0.564	0.566
18.05	0.570	0.568	0.569	18.05	0.570	0.568	0.569
18.00	0.572	0.570	0.571	18.08	0.569	0.567	0.568
18.05	0.570	0.568	0.569	18.10	0.569	0.567	0.568
17.99	0.572	0.570	0.571	18.20	0.566	0.5644	0.565
18.00	0.572	0.570	0.571	18.07	0.570	0.568	0.569
	Mean of Nos. 15–22				Mean of Nos. 23–30		
17.96	0.573	0.571	0.572	18.13	0.568	0.566	0.567

In order to eliminate this error he recommends to overtitrate the solution of the yellow precipitate in $\frac{n}{2}$ NaOH with from ½ c.c. to 1 c.c. of $\frac{n}{2}$ H_2SO_4, to drive off now the carbon dioxide by boiling, to cool and titrate back with $\frac{n}{2}$ NaOH. This, however, increases necessarily the time required for the titration of each individual analysis, aside from the fact that the liquid acidified with $\frac{n}{2}$ H_2SO_4 has the tendency somewhat to bump while boiling. Inasmuch as in Neumann's method it is indispensable to ascertain as to whether or not the reagents are free from phosphoric acid, the writers have found it to be more convenient to run a "blank" (preferably several "blanks") and to subtract the amount of standard alkali applied for neutralization of the "blank" from the result of the analysis proper. The figure secured for the blank analysis can advantageously be applied to a series of analyses, and it is evident that it does away with the necessity of removing carbon dioxide from the liquid to be titrated, since both the analysis and the "blank" contain practically the same amount of carbon dioxide. Thus eight blank analyses were made, in each of which there were employed 125 c.c. of distilled water, 10 c.c. of acid mixture, 75 c.c. of 50 per cent. ammonium nitrate, 40 c.c. of 10 per cent. ammonium molybdate, and one S. & S. filter of 12½ cm. diameter which was washed to neutrality (with either 50 c.c. or 150 c.c. of distilled water three times). Now each flask containing one washed filter received 150 c.c. of distilled water for reducing the filter to pulp, then 6 c.c. $\frac{n}{2}$ NaOH, whereupon contents were boiled for from fifteen to twenty minutes, cooled, made up to the original volume, and titrated. The blanks required for their neutralization on the average of concordant analyses 0.20 c.c. $\frac{n}{2}$ NaOH. The latter figure, which was applied to several series of analyses, was subtracted from the standard alkali used for each individual analysis and the so corrected figure recorded in the column in question.

---

[27] *Z. physiol. Chem.*, 53, 455 (1907).

[28] The factor in this table, like in the others, was calculated to the average of the gravimetric analysis (see Table I). No. 1, *e.g.*, has the factor $0.41171 \times \frac{25}{17.83} = 0.577$.

In glancing over the table we can readily see that the factor is to a certain degree influenced by the amount of water applied for washing the yellow precipitate. Numbers 1 to 8, the ammonium phosphomolybdate of which was washed with 150 c.c. of water, the washing being repeated four times, have the average factors of 0.578 (*a*), 0.576 (*b*), 0.577 (*c*); numbers 15 to 22, whose yellow precipitate was washed with 100 c.c. of water three times, have the average factors of 0.573 (*a*), 0.571 (*b*), 0.572 (*c*); while numbers 23 to 30, in which the washing of the yellow precipitate with 50 c.c. of water was performed three times, gave the smallest average factors of 0.568 (*a*), 0.566 (*b*), 0.567 (*c*). On the other hand, however, the numbers 9 to 14 and 15 to 22, the yellow precipitate of which was washed three times with 150 c.c. and 100 c.c. of water respectively, yielded the identical factors.

SERIES B.

Eight grammes of secondary ammonium phosphate [$(NH_4)_2HPO_4$] were dissolved in water, made up to about five litres, and the solution thoroughly shaken. In eight portions of this solution of 250 c.c. each the phosphorus was estimated according to the method of Fresenius, and in as many portions according to the method of Schmitz. The results are expressed in the following table:

TABLE III.

Number of analysis	$Mg_2P_2O_7$ found	
	(Fresenius)	(Schmitz)
	Gramme	*Gramme*
1	0.3393	0.3382
2	0.3388	0.3389
3	0.3391	0.3386
4	0.3386	0.3388
5	0.3398	0.3386
6	0.3397	0.3385
7	0.3404	0.3386
8	0.3385	0.3384
Mean (1-8)	0.3393	0.3386

Titration According to Neumann's Method.

Thirty-one portions of the above solution of 50 c.c. each were worked up according to Neumann's method. It goes without saying that the ammonium phosphomolybdate, prior to its titration, must be washed free from the adhering sulphuric and nitric acids with ice-cold water. Neumann[29] states that in order to obtain entirely neutral reaction of the filtrate the yellow precipitate has to be washed with 150 c.c. of ice-cold water, the washing being repeated from three to four times. As a matter of fact we have found that it is sufficient to wash the yellow precipitate on a 12½ cm. folded filter three times with but 50 c.c. of water. The filtrate was repeatedly tried by us with sensitive neutral litmus paper and was found to be neutral.

The results in question are summarized in Table IV.

---

[29] *Z. physiol. Chem.*, 37, 132 and 135 (1902–03).

TABLE IV.

$\frac{n}{2}$ NaOH used C.c.	Factor based on estimation of		$\frac{n}{2}$ NaOH used C.c.	Factor based on estimation of	
	(a) $Mg_2P_2O_7$ (Fresenius)	(b) $Mg_2P_2O_7$ (Schmitz)		(a) $Mg_2P_2O_7$ (Fresenius)	(b) $Mg_2P_2O_7$ (Schmitz)
32.80	0.576	0.575	32.85	0.575	0.574
33.10	0.571	0.570	32.93	0.574	0.572
33.22	0.569	0.568	32.95	0.573	0.572
32.98	0.573	0.572	32.88	0.575	0.573
32.74	0.577	0.576	33.01	0.572	0.571
33.00	0.573	0.571	32.95	0.573	0.572
32.74	0.577	0.576	32.92	0.574	0.573
32.74	0.577	0.576	32.85	0.575	0.574
32.70	0.578	0.577	32.90	0.574	0.573
Mean of Nos. 1–9			Mean of Nos. 10–18		
32.89	0.575	0.574	32.92	0.574	0.573
33.20	0.569	0.568	33.15	0.570	0.569
33.32	0.567	0.566	33.15	0.570	0.569
33.20	0.569	0.568	33.17	0.570	0.569
33.22	0.569	0.568	33.15	0.570	0.569
33.37	0.566	0.565	33.12	0.571	0.569
33.15	0.570	0.569	33.00	0.573	0.571
Mean of Nos. 19–30			33.19	0.569	0.568

An examination of the table reveals the fact that, while the influence on the factor of the amount of water employed for washing the yellow precipitate is small, yet it is distinct. Thus, numbers 1 to 9, the yellow precipitate of which was washed with 150 c.c. of ice-cold water, the washing being repeated three times, yielded the average factors of 0.575 (*a*), 0.574 (*b*). At the same time numbers 10 to 18, in which the washing of the yellow precipitate with 100 c.c. of water was performed three times, gave the average factors of 0.574 (*a*), 0.573 (*b*); while numbers 19 to 30, whose precipitate was washed with but 50 c.c. of water three times, gave the smallest average factors of 0.569 (*a*), 0.568 (*b*). On the whole the data of this series confirm the results of Series A, showing that, within certain limits, the factor is the higher the more water is employed for washing the yellow precipitate, and *vice versa*. In this connection it may be worth while here to mention that of all manipulations incident to Neumann's method the washing of the yellow precipitate in accordance with Neumann's directions is an operation not only tiresome but one requiring considerable time. The observation that it is sufficient to wash the phosphomolybdate of ammonia with three times 50 c.c. of water (instead of three or four times 150 c.c. of water) in order to obtain a neutral filtrate enables one to save more than half the time which was originally necessary for washing the yellow precipitate. We have also found that whenever the phosphoric acid is present in inorganic form it is advantageous to use, for the formation of the yellow precipitate and its washing, a round bottom flask of some 300 c.c. capacity, instead of a flask of from 500 c.c. to 750 c.c., as is ordinarily used in Neumann's method. In such cases where previous oxidation of organic matter with the acid mixture has to take place the substance is, on oxidation in the larger flask, transferred to the 300 c.c. flask with the aid of distilled water, which is, at all events, to be added before the formation of the ammonium phosphomolybdate takes place. The 300 c.c. flask is easier to handle during the repeated filtrations, and the yellow precipitate in it is more readily washed free from the adhering acids with a comparatively small amount of distilled water.

SERIES C.

A solution of 15 grammes of crystallized disodium hydrogen phosphate[30] in water which was made up to five litres was employed for the trials of this series. Of this solution eight 250 c.c. portions were analyzed gravimetrically according to Fresenius's method, eight like portions according to Schmitz's method, while five 50 c.c. portions were converted into sodium pyrophosphate by ignition. The results are recorded in the table below.

TABLE V.

Number of analysis	Found			Number of analysis	Found		
	(a) $Mg_2P_2O_7$ (Fresenius)	(b) $Mg_2P_2O_7$ (Schmitz)	(c) $Na_4P_2O_7$		(a) $Mg_2P_2O_7$ (Fresenius)	(b) $Mg_2P_2O_7$ (Schmitz)	(c) $Na_4P_2O_7$
	Gramme	*Gramme*	*Gramme*		*Gramme*	*Gramme*	*Gramme*
1......	0.2623	0.2626	0.0630	5......	0.2625	0.2617	0.0630
2......	0.2618	0.2623	0.0630	6......	0.2631	0.2621	......
3......	0.2630	0.2627	0.0630	7......	0.2631	0.2618	......
4......	0.2630	0.2630	0.0632	8......	0.2630	0.2614	......
Mean................................					0.2627	0.2622	0.0630

---

[30] The crystals have in part lost their water of crystallization.

Titration According to Neumann's Method.

Twenty-four portions of the above solution of 50 c.c. each were titrated according to Neumann. The data in question are contained in Table VI. The figures in columns 1 and 5 of the table represent the standard alkali used for each individual analysis minus 0.20 c.c. $\frac{n}{2}$ NaOH required for neutralization of the acidity found in the blank analysis. In connection with the blank analysis it may be mentioned here that on addition of ammonium molybdate to the heated mixture of water, acid mixture, and ammonium nitrate the solution remained water-clear. On standing it gave neither a precipitate nor even a faint yellow color, showing that the reagents were free from phosphoric acid. Since, however, the blank analyses yielded an acidity equivalent to 0.20 c.c. $\frac{n}{2}$ NaOH it was logical to suppose, as we did, that the acidity was caused by the action of the alkali on the filter paper. This was actually confirmed by the direct experiment. Each of six round-bottom flasks received a S. & S. filter (of 12½ cm. diameter) which was reduced to pulp with the aid of 150 c.c. of distilled water. The flasks, with their contents, to each of which 10 c.c. $\frac{n}{5}$ NaOH had been added, were now heated to the boiling-point and kept boiling for from fifteen to twenty minutes, whereupon they were cooled, filled up to original volume, and titrated back with $\frac{n}{5}$ H_2SO_4, phenolphthalein being used as indicator. On the average of concordant titrations, each filter required for its neutralization 0.49 c.c. $\frac{n}{5}$ NaOH, which is identical with the acidity of the blank analyses (0.20 c.c. $\frac{n}{2}$ NaOH). When this experiment was repeated, with the only difference that the filter pulp was boiled *without* the addition of 10 c.c. $\frac{n}{5}$ NaOH, it was found that the filter pulp gave neutral reaction in each case, showing that the filters and water were neutral.

A glance at the table shows that numbers 1 to 12 and numbers 13 to 24, whose yellow precipitate was washed with three times 150 c.c. and 50 c.c. of ice-cooled water respectively, have the identical average factors, thus showing in this case no visible influence of the quantity of wash water on the factor.

TABLE VI.

$\frac{n}{2}$ NaOH used C.c.	Factor based on estimation of			$\frac{n}{2}$ NaOH used C.c.	Factor based on estimation of		
	(a) $Mg_2P_2O_7$ (Fresenius)	(b) $Mg_2P_2O_7$ (Schmitz)	(c) $Na_4P_2O_7$		(a) $Mg_2P_2O_7$ (Fresenius)	(b) $Mg_2P_2O_7$ (Schmitz)	(c) $Na_4P_2O_7$
25.65	0.570	0.569	0.572	25.52	0.573	0.572	0.575
25.45	0.575	0.574	0.577	25.65	0.570	0.569	0.572
25.65	0.570	0.569	0.572	25.65	0.570	0.569	0.572
25.63	0.571	0.570	0.573	25.62	0.571	0.570	0.573
25.60	0.572	0.571	0.574	25.58	0.572	0.571	0.574
25.65	0.570	0.569	0.572	25.61	0.571	0.570	0.573
Mean of Nos. 1–12........			....	25.61	0.571	0.570	0.573
25.45	0.575	0.574	0.577	25.80	0.567	0.566	0.569
25.58	0.572	0.571	0.574	25.60	0.572	0.570	0.574
25.71	0.569	0.568	0.571	25.53	0.573	0.572	0.575
25.62	0.571	0.570	0.573	25.62	0.571	0.570	0.573
25.60	0.572	0.570	0.574	25.65	0.570	0.569	0.572
25.60	0.572	0.570	0.574	25.50	0.574	0.573	0.576
Mean of Nos. 13–24.......			....	25.61	0.571	0.570	0.573

SERIES D.

Ten grammes of 85 per cent. phosphoric acid made up to five litres were used for the trials of this series. In seven 100 c.c. portions of this solution the phosphorus was estimated gravimetrically according to the method of Fresenius, and in eight like portions according to the method of Schmitz, with the results summarized in Table VII.

TABLE VII.

Number of analysis	$Mg_2P_2O_7$ found		Number of analysis	$Mg_2P_2O_7$ found	
	(Fresenius)	(Schmitz)		(Fresenius)	(Schmitz)
	Gramme	*Gramme*		*Gramme*	*Gramme*
1..........	0.2096	0.2085	5..........	0.2097	0.2090
2..........	0.2099	0.2079	6..........	0.2099	0.2090
3..........	0.2102	0.2085	7..........	0.2100	0.2086
4..........	0.2102	0.2086	8..........	......	0.2088
Mean..................................				0.2099	0.2086

Twenty-six portions of the same solution of 25 c.c. each were treated according to Neumann. The data are recorded in Table VIII.

TABLE VIII.

$\frac{n}{2}$ NaOH used C.c.	Factor based on estimation of		$\frac{n}{2}$ NaOH used C.c.	Factor based on estimation of	
	(*a*) $Mg_2P_2O_7$ (Fresenius)	(*b*) $Mg_2P_2O_7$ (Schmitz)		(*a*) $Mg_2P_2O_7$ (Fresenius)	(*b*) $Mg_2P_2O_7$ (Schmitz)
25.28	0.578	0.574	25.25	0.579	0.575
25.25	0.579	0.575	25.38	0.576	0.572
25.18	0.580	0.577	25.30	0.578	0.574
25.30	0.578	0.574	25.15	0.581	0.577
25.28	0.578	0.574	25.30	0.578	0.574
Mean of Nos. 1–10................			25.27	0.578	0.575
25.32	0.577	0.574	25.30	0.578	0.574
25.42	0.575	0.571	25.40	0.575	0.572
25.30	0.578	0.574	25.10	0.582	0.579
25.35	0.577	0.573	25.40	0.575	0.572
Mean of Nos. 11–18...............			25.32	0.577	0.574
25.70	0.569	0.565	25.70	0.569	0.565
25.75	0.568	0.564	25.60	0.571	0.568
25.73	0.568	0.564	25.70	0.569	0.565
25.80	0.566	0.563	25.85	0.565	0.562
Mean of Nos. 19–26..............			25.73	0.568	0.565

In glancing over the table we can readily see that the numbers 1 to 10, the yellow precipitate of which was washed with 150 c.c. of ice-cooled water four times, gave the average factors of 0.578 (*a*) and 0.575 (*b*); the numbers 11 to 18, whose yellow precipitate was washed with 100 c.c. of water three times, yielded the average factors of 0.577 (*a*) and 0.574 (*b*); while the numbers 19 to 26, whose precipitate was washed with but 50 c.c. of water three times, yielded the smallest average factors of 0.568 (*a*) and 0.565 (*b*). Thus this series corroborates the results of Series A and B, in that the amount of wash water has a distinct though small influence on the factor.

SERIES E.

Pulverized, oven-dried disodium hydrogen phosphate (37.5 grammes) dissolved in water and made up to about nine litres was used for the experiments of this series. In ten portions of this solution of 50 c.c. each the phosphorus was estimated gravimetrically according to the method of Fresenius, in eight like portions according to Schmitz, while in other three portions the phosphorus was by ignition converted into pyrophosphate. The results are recorded in Table IX.

TABLE IX.

Number of analysis	Found (a) $Mg_2P_2O_7$ (Fresenius)	Found (b) $Mg_2P_2O_7$ (Schmitz)	Found (c) $Na_4P_2O_7$	Number of analysis	Found (a) $Mg_2P_2O_7$ (Fresenius)	Found (b) $Mg_2P_2O_7$ (Schmitz)	Found (c) $Na_4P_2O_7$
	Gramme	*Gramme*	*Gramme*		*Gramme*	*Gramme*	*Gramme*
1......	0.1632	0.1627	......	6.....	0.1642	0.1629	0.1950
2......	0.1650	0.1627	......	7.....	0.1632	0.1628	0.1952
3......	0.1631	0.1627	......	8.....	0.1637	0.1630	0.1942
4......	0.1639	0.1632	......	9.....	0.1634	......	......
5......	0.1647	0.1628	......	10.....	0.1628	......	......
Mean..................................					0.1637	0.1629	0.1948

From the analytical data it follows that 1 c.c. of the solution contains respectively 0.91184, 0.90727, and 0.90809 mg. P according to methods (*a*), (*b*), and (*c*).

Thirty other portions of the above solution of 10 c.c. each were treated according to Neumann's method. The data are summarized in Table X.

TABLE X.

$\frac{n}{2}$ NaOH used *C.c.*	Factor based on estimation of (a) $Mg_2P_2O_7$ (Fresenius)	Factor based on estimation of (b) $Mg_2P_2O_7$ (Schmitz)	Factor based on estimation of (c) $Na_4P_2O_7$	$\frac{n}{2}$ NaOH used *C.c.*	Factor based on estimation of (a) $Mg_2P_2O_7$ (Fresenius)	Factor based on estimation of (b) $Mg_2P_2O_7$ (Schmitz)	Factor based on estimation of (c) $Na_4P_2O_7$
15.80	0.577	0.574	0.575	15.71	0.580	0.578	0.578
15.80	0.577	0.574	0.575	15.80	0.577	0.574	0.575
15.81	0.577	0.574	0.575	15.80	0.577	0.574	0.575
15.78	0.578	0.575	0.575	15.74	0.579	0.576	0.576
15.80	0.577	0.574	0.575	15.79	0.577	0.575	0.575
15.78	0.578	0.575	0.575	15.80	0.577	0.574	0.575
15.78	0.578	0.575	0.575	15.90	0.573	0.571	0.571
15.70	0.581	0.578	0.578	.....	.....	.....	.....
Mean of Nos. 1–15...............				15.79	0.577	0.575	0.575
15.71	0.580	0.578	0.578	15.70	0.581	0.578	0.578
15.71	0.580	0.578	0.578	15.76	0.579	0.576	0.576
15.69	0.581	0.578	0.578	15.68	0.582	0.579	0.579
15.62	0.584	0.581	0.581	15.72	0.580	0.577	0.578
15.62	0.584	0.581	0.581	15.68	0.582	0.579	0.579
15.71	0.580	0.578	0.578	15.70	0.581	0.578	0.578
15.70	0.581	0.578	0.578	15.70	0.581	0.578	0.578
15.68	0.582	0.579	0.579	.....	.....	.....	.....
Mean of Nos. 16–30................				15.69	0.581	0.578	0.578

An examination of the table reveals the fact that the individual factors obtained by method (*a*) agree very well with each other. This holds also good for the individual factors secured by methods (*b*) and (*c*). The numbers 1 to 15, whose yellow precipitate was washed with 150 c.c. of ice-cold water, the washing being performed three times, yielded the average factors 0.577 (*a*), 0.575 (*b*), and 0.575 (*c*), while the numbers 16 to 30, whose precipitate was washed with 150 c.c. of water four times, gave the higher average factors 0.581 (*a*), 0.578 (*b*) and 0.578 (c). Thus the figures of this series confirm the results secured in Series A, B, and D in that, within certain limits, the factor is the higher the more water is used for washing the yellow precipitate, and *vice versa*.

The average factors for all five series (based on all three methods) were as follows:

0.577, when precipitate was washed with four times 150 c.c. of ice-cold water;
0.573, when precipitate was washed with three times 150 c.c. of ice-cold water;
0.573, when precipitate was washed with three times 100 c.c. of ice-cold water;
0.568, when precipitate was washed with three times 50 c.c. of ice-cold water.

The mean factors in the various series—despite the fact that they were washed with the same amount of water—were rather subjected to some variation. This must be ascribed to the fact that the factors are influenced not only by the amount but also by the temperature of the wash [31] water, as well as by the time of contact of the water with the yellow precipitate, which in some measure depends upon the physical qualities of the filter and of the yellow precipitate itself. Since we are not fully in control of the latter two factors, it is obvious that the time during which the yellow precipitate is in contact with the wash water will vary to a certain degree, while, on the other hand, even with the greatest care it is not infrequently impossible to prevent traces of the yellow precipitate from going through the filter. On the whole, however, it seems safe to state that the tendency of the factor to grow, within certain limits, with increasing amounts of wash water follows from the data at hand.

---

[31] The temperature of the wash water which was cooled in a refrigerator was not quite uniform, because of the somewhat changing temperature within the refrigerator.

The latter conclusion made it appear of interest quantitatively to determine the amount of phosphorus which is lost in filtrate and washings from the yellow precipitate. It seemed probable that the washings (plus filtrate) would contain different amounts of phosphorus when the yellow precipitate is washed with different quantities of water. Hence experiments were carried out for which a disodium hydrogen phosphate solution was used, 1 c.c. of which was gravimetrically found to contain 0.90907 milligramme phosphorus. In six portions of this solution of 20 c.c. each the ammonium phosphomolybdate precipitate was obtained exactly as outlined elsewhere,[32] and, on filtration, was washed with 150 c.c. of ice-cold water, the washing being repeated four times. The six filtrates and the corresponding washings were combined and evaporated on the steam-bath. As the concentration went on the liquid gradually became intensely yellow. The evaporation was continued to beginning crystallization, when the residue was quantitatively transferred to a round-bottom flask, cooled, dissolved in water under addition of dilute ammonia, and filtered until perfectly clear. This filtrate was now neutralized with nitric acid, 30 c.c. more of concentrated nitric acid were added (total volume was now about 500 c.c.) and heated to 80° C. On standing, the yellow precipitate came slowly down. It was filtered out (after about one hour), washed with ice-cold water until wash water was neutral, and titrated after the ammonia had been driven off. The recovered yellow precipitate required 1.85 c.c. $\frac{n}{2}$ NaOH for its neutralization. Filtrate and washings from this precipitate were combined, again evaporated and treated as outlined. The yellow precipitate (second recovery) now obtained required 0.30 c.c. $\frac{n}{2}$ NaOH. Filtrate and washings from the second precipitate, when evaporated and treated again as outlined, did not give any further precipitate. This experiment was repeated with varying amounts of the phosphorus solution. The results are recorded in Table XI.

---

[32] *Jour. Amer. Chem. Soc.*, 37, 1709 (1915).

TABLE XI.

Loss of Phosphorus in Filtrate and Washings.

No.	Na_2HPO_4 used		Yellow precipitate washed with ice-cold water		The yellow precipitate (recovered from filtrates and washings) required for its neutralization	Corresponding total phosphorus	
	C.c.	Corresponding phosphorus Mgrs.	*C.c.*	Times	$\frac{n}{2}$ NaOH, *C.c.*	Mgrs.	Per cent. of phosphorus applied
1.....	6×20	109.0884	150	4	1.85 (First recovery) 0.30 (Second recovery)	1.2255	1.12
2.....	3×20	54.5442	150	4	1.02	0.5814	1.07
3.....	6×15	81.8163	150	4	2.08 (First recovery) 0.83 (Second recovery)	1.6587	2.03
4.....	6×10	54.5442	150	4	2.31 (First recovery) 0.15 (Second recovery)	1.4022	2.57
5.....	6×5	27.2721	150	4	1.70 (First recovery) 0.19 (Second recovery)	1.0773	3.95
6.....	6×20	109.0884	50	3	1.50 (First recovery) 0.20 (Second recovery)	0.9690	0.89
7.....	6×15	81.8163	50	3	1.80 (First recovery) 0.55 (Second recovery)	1.3395	1.64
8.....	6×10	54.5442	50	3	1.25 (First recovery) 0.40 (Second recovery)	0.9405	1.72
9.....	6×5	27.2721	50	3	1.08 (First recovery) 0.45 (Second recovery)	0.8721	3.20

TABLE XII.

No.	Na_2HPO_4 used		Yellow precipitate washed with ice-cold water		The yellow precipitate (recovered from filtrate only) required for its neutralization	The yellow precipitate (recovered from washings only) required for its neutralization	Corresponding phosphorus	
	C.c.	Corresponding phosphorus Mgs.	*C.c.*	Times	$\frac{n}{2}$ NaOH *C.c.*	$\frac{n}{2}$ NaOH *C.c.*	Mgs.	Per cent. of phosphorus applied
1.....	10×20	181.814	150	4	1.26	....	0.7182	0.40
					....	1.83	1.0431	0.57
2.....	10×20	181.814	50	3	1.40	....	0.7980	0.44
					....	1.10	0.6270	0.34
3.....	10×10	90.907	150	4	1.23	....	0.7011	0.77
					....	1.33	0.7581	0.83
4.....	10×10	90.907	50	3	1.18	....	0.6726	0.74
					....	1.03	0.5871	0.65

It seemed also desirable to ascertain whether and how much of phosphorus is lost in the *filtrate* from the yellow precipitate only. Hence experiments were made similar to those recorded in Table XI, with the difference that the filtrates on the one hand and the washings on the other were separately evaporated and treated as outlined above. The results are summarized in Table XII.

CONCLUSIONS.

1. The factor used for the calculation of phosphoric acid in Neumann's method is to a certain degree influenced by the amount of water used for washing the ammonium phosphomolybdate precipitate. The larger the amount of wash water, the higher is the factor within certain limits, and *vice versa.*

2. When the yellow precipitate was washed with four times 150 c.c. of ice-cold water, the losses of phosphorus in filtrate plus washings ranged from 1.07 to 3.95 per cent. of the phosphorus employed. By washing the precipitate with but three times 50 c.c. of water the corresponding losses were smaller; namely, they ranged from 0.89 to 3.20 per cent. (Table XI). This explains in part why the factor rises with increasing amounts of wash water.

3. The more substance (phosphorus) is employed in Neumann's method, the smaller is the percentage of phosphorus lost in filtrate and washings, and *vice versa.*

4. The ammonium phosphomolybdate is not absolutely insoluble in the liquid from which it is precipitated, the losses of phosphorus ranging in the experiments reported from 0.40 to 0.77 per cent. of the phosphorus employed (Table XII).

5. Instead of washing the ammonium phosphomolybate precipitate with 150 c.c. of ice-cold water, the washing being repeated from three to four times, as is recommended by Neumann, it is sufficient to wash it with three times 50 c.c. of water, which enables one to save time and labor. It is, further, more convenient to use, for the formation of the yellow precipitate and its washings, a 300 c.c. round-bottom flask, instead of a flask of from 500 to 750 c.c., as is commonly used in Neumann's method. The latter flask is, however, to be used for oxidation of organic matter, if present.

WASHINGTON, D. C.

External Corrosion of Cast-iron Pipe. M. R. PUGH. (*The American Gas Light Journal,* vol. ciii, No 5, August 2, 1915.)—In a paper read before the American Society of Civil Engineers the author mentions instances, both here and abroad, in which cast-iron water-pipe has remained in perfect condition after a hundred years' service or more when laid underground or immersed in fresh water. When, however, they have been laid in salt marshes or immersed in sea water their useful life is measured by a few years only. From a comprehensive analysis of the subject the following conclusions are reached: (1) Under ordinary conditions of soil, cast-iron pipe has a probable life of from one to three centuries, so far as external corrosion is concerned. (2) Under certain soil conditions, such as salt marshes or saline soils, cast-iron pipe may be rendered useless in from seven to twenty years. (3) At times cinder and slag fills may exert a strongly deleterious influence. Acid mine waters are also destructive. (4) Substituting wrought iron or steel pipe for cast iron is ineffectual. Cast iron will outlast the others. (5) Remedies fall under four heads: (*a*) Increasing the skin resistance of cast iron; (*b*) utilizing the protective influence of alkalies by surrounding the pipe with lime or cement where practicable; (*c*) exclusion of acids, salt, or air; (*d*) galvanizing the cast-iron pipe, thus protecting it at the expense of the zinc.

The Thermal Efficiency of the Electric Furnace. W. MCA. JOHNSON. (*Proceedings of the Engineers' Society of Western Pennsylvania,* vol. 31, No. 6, July, 1915.)—It does not appear commercially possible to use the electric furnace in direct competition with the coal- or gas-fired furnace. A ton of coal of 11,147 B. T. U.'s per pound has the same number of heat units as a horse-power year. A short ton of coal in the Pittsburgh district costs about one dollar. A horse-power year will cost in the same locality from $30 to $60. This means that the cost of electrically-generated heat in this district is from thirty to sixty times as great as the cost of heat in coal. In Norway energy is sold at ridiculously low prices. There is a great deal of water-power running to waste. It has a high head, a nearly constant flow, and the cost of installation is low. On reliable information it is stated that contracts are made at as low a figure as $5 per horse-power year. But even under these extremely favorable conditions the electric furnace using iron ore and burning out pig iron has not been a commercial success. There are many iron blast furnaces using coke and charcoal in Norway and Sweden and only a few electric pig-iron furnaces. If in these countries the electric pig-iron furnace cannot compete, or compete only with difficulty, we cannot hope for it to compete in Chicago or Pittsburgh.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

ANTENNA RESISTANCE.

By L. W. Austin.

[ABSTRACT.]

THE resistance of a radiotelegraphic antenna may be divided into three parts: first, the ohmic resistance of the wires; second, the so-called radiation resistance; and, third, the so-called earth resistance. The first is generally negligible where a sufficient number of wires in parallel is used. The second is derived from the expression for the radiated energy of an antenna, which is

$$E = 160\pi^2 \frac{h^2}{\lambda^2} \cdot I_s^2$$

where h represents the height to the centre of capacity of the antenna, λ the wave-length, and I_s the current measured at the base of the antenna. The expression $160\pi^2 \frac{h^2}{\lambda^2}$ is called the radiation resistance, as it takes the same position in the energy equation as that occupied by R in the case of ohmic losses. The expression shows that the radiation resistance falls rapidly as the wave-length is increased.

Up to the present no satisfactory theory of ground resistance has been developed. The experimental curves of antenna resistance, on account of the decreasing radiation resistance, fall rapidly at first, as the wave-length is increased, and then, as the wave-length is further increased, remain nearly constant if the ground conditions are good, as in the case of a ship's antenna, or again rise nearly in a straight line if the ground conditions are poor. This rise may be very rapid in the case of peculiarly poor grounds. For instance, the resistance of the Bureau of Standards antenna rises from 13 ohms at 800 metres wave-length to 28 ohms at 2000 metres. Great difficulty has been found in explaining this increase of resistance with increasing wave-length, but it is believed that the following explanation is the true one: The antenna system must be looked upon as a condenser, the antenna itself being the upper plate and the ground water the lower plate. Between the ground water and the surface there is usually a layer of semi-conducting material which would correspond to a poor dielectric in the case of an ordinary condenser. It is well known that the dielectric losses in imperfect condensers generally increase in proportion to the wave-length of the current employed in the measurement. It is found that by covering the surface of the ground under and around the antenna with a wire net, thus making the net the lower plate of the condenser, the ground losses nearly disappear.

---

* Communicated by the Bureau.

A PRELIMINARY REPORT ON ELECTROLYSIS MITIGATION IN ELYRIA, OHIO.

By Burton McCollum and K. H. Logan.

[ABSTRACT.]

THIS report is based on data furnished the Bureau of Standards by the city of Elyria and the Cleveland, Southwestern & Columbus Railway Company. The data show that the feeding distances of the power-house located a little south of the city limits are long, and, as a consequence, the overall potentials, potential gradients, and potential differences between pipes and rails are too high for safe electrolysis conditions.

The report recommends that the rail gradients be reduced to 0.3 volt per 1000 feet average for 24 hours, which corresponds to maximum value for the 15-minute peak to about 0.75 volt per 1000 feet. To obtain this low gradient economically three changes in the present method of operation are proposed.

A substation should be located at Chestnut, approximately half-way between Elyria and Ridgeville, and the substation at Penfield should take part of the load originating between it and Elyria. The tracks of the Cleveland, Southwestern & Columbus and the Lake Shore Electric Railways should be interconnected at West and Mill Streets, and an insulated return feeder system should be installed to reduce the gradients on Middle Avenue.

Enough copper can be removed from the present positive feeder system after the installation of the Chestnut substation to provide for the return feeders.

The total investment required for the proposed changes is estimated as $34,373. The power saved by the proposed changes

is shown to be more than sufficient to pay all annual charges on the proposed installation and leave a net profit of about $1600 per year. A further advantage of the proposed plan is the provision of 800 kilowatts additional reserve substation capacity and improved operating conditions.

A system of potential wires extending from some central point to the point of lowest potential on the track and to the points of highest potential within the city on each line is recommended.

SPECIAL STUDIES IN ELECTROLYSIS MITIGATION.

3. A REPORT ON CONDITIONS IN SPRINGFIELD, OHIO, WITH INSULATED FEEDER SYSTEM INSTALLED.

By Burton McCollum and G. H. Ahlborn.

This report concerning electrolysis conditions in Springfield, Ohio, deals with the electrolysis situation with the completed mitigation systems in operation and the track return much improved.

Before presenting the data taken in the survey the general condition of city and the public utilities which might affect electrolysis are discussed. The insulated return feeder system is described in detail, the description including data on cables and resistance taps and a map of the systems. The permanent pressure wire system installed to obtain overall potential measurements is described in detail.

The cost of railway operation as it is affected by the mitigation system is shown to be slightly greater than it was before any system was installed. This is due to the investment in copper, the power losses being about the same. The cost is less than with the first mitigation system in operation, chiefly because the power losses have been reduced. The annual charges on the feeders are shown in detail.

The methods employed in obtaining the data are discussed and the correction and reduction factors that must be applied to the various sets of readings are given, the data being reduced to average values for the 24-hour and maximum hour periods.

The data were obtained in July and August, 1914, and are discussed under the heads, Potential Differences, Potential Gradients, Overall Potentials, and Stray Currents in Underground Structures. The potential differences between pipes and rails show that all values are well below one volt for the all-day average, and at only two points do the values for the maximum hour reach one volt. The potential differences between gas and water mains are practically zero, and the lead sheaths are everywhere negative to the other structures and ground. The potential gradients are low on all sections of track, and on all repaired sections not substantially insulated from ground the overall potentials are less than 3 volts for the all-day average values. There were still two or three sections not completely bonded or practically insulated from earth where the drop was over 3 volts. The stray current in the underground structures is practically negligible at all points, that in the gas mains being especially low. There are a few points where tracks lie near each other where local potential differences should be further reduced by cross-ties between such tracks. The potential differences existing in such places are shown and the amount of copper necessary for the cross-ties is stated: In reviewing the above data it is pointed out that the structures are comparatively safe and the results obtained satisfactory.

The data obtained during the summer of 1914 are compared with similar data taken in the survey of the previous winter to determine any effect of frost and lower temperatures. The loads on the interurban lines are about the same during both seasons, but decidedly heavier on the Springfield Railway during the winter. Taking this into consideration, as well as the increased conductivity of the rails in cold weather, it is evident that the potential differences are greater because of the frost, but that the stray currents are reduced.

Recommendations are made concerning improvement in track bonding, precautions that should be taken in the laying of new pipes and repairing old ones, and supervision and inspection by the city officials in order to maintain good electrolysis conditions. It is recommended that the insulated return feeder system be continued in operation and annually inspected, that the sections of track mentioned in the report as in bad condition be repaired, that certain interconnections between tracks be made, and that the pressure wire system now installed be maintained. It is also recommended that no pipe drainage and only limited lead sheath drainage be permitted, that pipe-owning companies install new mains and services so as to pick up as little stray current as possible, and insert insulating joints in new mains and services where these are in close proximity to railway lines.

The city is urged to adopt 3 volts average for the 24-hour period as the overall voltage limit, except on two lines, where 4 volts may be permitted; to require rebonding of rail joints where their resistance exceeds that of ten feet of rail; to require annual tests and reports of bonding conditions, and to appoint a city expert to determine overall potentials and pass on the above tests and reports.

A METHOD FOR MEASURING EARTH RESISTIVITY.

By Frank Wenner.

[ABSTRACT.]

A knowledge of earth resistivity may be of value in determining something of its composition, such, for example, as moisture content, whether or not it contains oil or ore of high conductivity, etc., or in the calculation of damages to pipe systems by the return current of street railway systems. For some of these or other reasons we may wish to determine the resistivity of limited portions of the earth.

For those cases in which we desire the resistivity of a fairly large portion of earth, extending to a considerable depth, or where there are reasons why the measurement should be made without disturbing the portion to be measured, the following method is suggested:

Four holes are made in the earth approximately uniformly spaced in a straight line. The diameter of the holes is not more than 10 per cent. of the distance between them and all extend to approximately the same depth, which is usually that at which we are most concerned with the resistivity. In each hole is placed an electrode which makes electrical contact with the earth only near the bottom. Two of these electrodes serve as current terminals and two as potential terminals in the measurement of the resistance.

Knowing the resistance, the depth of the holes, and the distance between them, we have data from which the effective resistivity in the vicinity can be calculated.

In case a is the distance between the holes, b is the depth of

the holes, ρ is the resistivity, and R the measured resistance, then

$$\rho = \frac{4\pi aR}{1 + \frac{2a}{\sqrt{a^2 + 4b^2}} - \frac{2a}{\sqrt{4a^2 + 4b^2}}} = \frac{4\pi aR}{n} \qquad (1)$$

where n varies between 1 and 2 according to the ratio of the depth of the electrodes to their distance apart. If the holes are not in a straight line or are not of a uniform depth or spacing, the resistivity is easily calculated from the depth of each of the holes and the distance of each from each of the other three.

Concerning the resistance measurements, there is in general no need for a high accuracy. There is, therefore, no reason why we may not use an ammeter for measuring the current and a voltmeter for measuring the resulting difference in potential between the potential terminals, providing no current is drawn from these terminals. As the voltage to be measured is low and the resistance between electrodes and earth high, errors would be introduced if the ammeter-voltmeter method were used in the ordinary way.

The following potentiometer arrangement, using alternating current to obviate the more serious difficulties which might arise on account of polarization with direct current, seems to answer the purpose fairly well. The current terminal or electrodes are connected to a source of alternating voltage of suitable value, and across the line is connected a step-down transformer, the low-voltage side of which is connected to the ends of a slide wire. One of the potential terminals is connected to one end of the slide wire and the other, through a vibration galvanometer, to the adjustable contact on the slide wire. An ammeter is connected into a lead to one of the current and a voltmeter across the ends of the slide wire. On account of the polarization at the current electrodes a variable inductance is connected into one end of the leads, for the purpose of bringing the test current in phase with the voltage of the low side of the transformer.

If, then, adjustments are made so that no current flows through the galvanometer, the position of the sliding contact, the value of the test current, and the voltage across the slide wire are read, we have data from which the resistance R is readily calculated.

From the measured resistance, and the depth and distance between electrodes, a value may be obtained for the effective resistivity as explained above. The value depends mainly upon the resistivity in the neighborhood of and between the potential electrodes, and very little upon the resistivity at distances from either of these electrodes equal to half the distance between the current electrodes.

So far the method has been used only for determining resistivities in a region very close to the surface, a few metres or less in radius. To measure the effective resistance of a much larger portion of earth extending to a considerable depth, the electrodes would be placed much farther apart. Such a measurement might be of assistance in locating deposits of ore of high conductivity.

INTERFERENCE MEASUREMENT OF WAVE-LENGTHS IN THE IRON SPECTRUM (2851-3701).

By Kewin Burns.

THE determination of accurate wave-lengths in the spectra of iron and of other elements has recently been undertaken by the Bureau of Standards. The need for wave-length determinations of great accuracy has long been felt by physicists, chemists, and astronomers. As an example, it is impossible to make a complete spectral analysis of iron, owing to our lack of exact knowledge of the spectra of some elements of the ferrous group. Before any reliable wave-lengths can be obtained there must necessarily be a consistent fundamental system. On account of the irregularities existing in the Rowland system of wave-lengths, an international conference of eminent spectroscopists has recommended the adoption of a new system of wave-lengths based on the length of the red cadmium line as determined by Benoit, Faby, and Perot by direct comparison with the meter. In this system, by means of the interferometer, secondary standards are to be determined in the iron spectrum at intervals of 10A (0.001μ); that is, the wave-length of each standard is to differ by 10 A from the wave-length of its nearest neighbors to the violet and red. The Bureau of Standards has undertaken to do the part of this work for which the present need seems to be the greatest, and this paper presents the first instalment of wave-lengths to be measured here in keeping with the international plan.

The spectrograms upon which this work is based were obtained at Marseilles, in the laboratories of Messrs. Buisson and Faby.

The interferometer plates were quartz disks whose inner surfaces were coated with a semi-transparent film of nickel. The light from the iron arc was focussed on these plates by a quartz lens, and the resulting rings were projected upon the slit of the spectrograph by means of an achromatic lens made of quartz and fluorite. The light passing through the slit was drawn out into a spectrum by means of a 21-inch Rowland grating mounted in parallel light. In this way each line in the iron spectrum is photographed as the diameter of a system of interference rings. By measuring the diameters of these rings the wave-lengths were found by the method of Buisson and Faby. A Michelson cadmium tube furnished the standard red line, the rings from which were photographed before and after each exposure on the iron. Between the limits 2851 A and 3701 A, 131 wave-lengths were measured. Where it was found possible, faint lines as well as strong ones were measured. Throughout the greater part of the region lines were measured at intervals of 10 A or less. The accuracy of the measurements appears to be about one part in two millions; in other words, the wave-lengths are accurate to one five-hundred-millionth of a millimetre.

A Chain Fire-door Screen. ANON. (*Power,* vol. 42, No. 3, July 20, 1915.)—When a furnace door is opened cold air rushes in, chills the highly-heated brickwork and the boiler shell causes contraction of the plate, and lowers the temperature of the combustible gases. To overcome these objectionable features a simple device known as the Wiegand auxiliary chain screen door has been designed. The chain door contains numerous separately hanging strands of small steel chain suspended from a cylinder extending across the top of the furnace door, with the chains hung as close together as possible, forming a continuous sheet, somewhat after the fashion of the common window shade. Opening the door automatically unrolls the chain and covers the opening, preventing to a great extent the escape of heat and checking the entrance of cold air. The screen does not interfere either with cleaning the fires or charging the furnace with fresh fuel.

An idea of the results obtained with the device may be gathered by placing a thermometer ten inches in front of the opening. Without the screen the temperature rises to 400° F. When the opening is covered by the screen the temperature registers 135°, a difference of 265°. With the furnace door closed and the screen rolled up the thermometer shows 110°.

THE FRANKLIN INSTITUTE

LIBRARY NOTES.

PURCHASES.

Bjerknes, C. A.—Hydrodynamische Fernkräfte. 1915.
Butler, E.—Oil Fuel. 1914.
Conklin, C. D., Jr.—Structural Steel Drafting and Elementary design. 1915.
Cooper-Key, A.—Primer on the Storage of Petroleum Spirit. 1914.
Coste, J. H., and E. R. Andrews.—Examination and Thermal Value of Fuel. 1914.
Cressy, E.—Discoveries and Inventions of the Twentieth Century. 1915.
Johnson, G. L.—Photography in Colors. 1914.
Lauchli, E. Tunnelling. 1915.
Mellor, J. W.—Clay and Pottery Industries. 1914.
Robinson, R. H. M.—Naval Construction. 1915.
Russell, E. J.—Soil Conditions and Plant Growth. 1915.
West Virginia Geological Survey.—Boone County Reports. 2 volumes. 1915.

GIFTS.

Anglo-Mexican Petroleum Products Company, Ltd., Mexican Fuel Oil. London, no date. (From the Company.)
Canada Department of Mines, Report of Geological Survey; Memoir 69, Coal Fields of British Columbia. Ottawa, 1915. (From the Department.)
Iowa State College of Agriculture and Mechanic Arts, General Catalogue, 1915; Bulletins Nos. 33-38. Ames. no date. (From the College.)
Leland Stanford Junior University, The Pronoun of Address in English Literature of the Thirteenth Century, and The Anoplura and Mallophaga of North American Mammals. Stanford University, Cal., 1915. (From the University.)
Liverpool Corporation Tramways, Annual Report, 1914. Liverpool, 1915. (From Mr. C. W. Mallins, General Manager.)
National Fire Protection Association, Proceedings, Nineteenth Annual Meeting. New York, 1915. (From the Association.)
New South Wales Department of Mines, Annual Report, 1914. Sydney, 1915. (From the Department.)
New York Public Service Commission, Second District, Eighth Annual Report, 1914. Albany, 1915. (From the Commission.)
Pennsylvania Department of Fisheries, Report, 1914. Harrisburg, 1915. (From the State Librarian.)
Pennsylvania Public Service Commission, First Annual Report, 1913-14. Harrisburg, 1915. (From the State Librarian.)

Philadelphia Maritime Exchange, Fortieth Annual Report. Philadelphia, 1915. (From the Exchange.)

St. Louis Water Commissioner, Annual Report. St. Louis, 1915. (From the Commissioner.)

Temple University, Annual Catalogue, 1915–16. Philadelphia, 1915. From the University.)

Thompson, W. P., and Company, Handbook of Patent Law of All Countries. London, 1915. (From the Company.)

Tokyo Imperial University, Journal of the College of Science, vols. xxxv, art. 8, and xxix, art. 1. Tokyo, 1914. (From the University.)

U. S. Bureau of Mines, Technical Papers 39, 63, 68, 84, 99, 100; Miners' Circulars 11, 15; Bulletins, 17, 20, 24, 27, 28, 29, 31, 32, 33, 34, 35, 40, 51, 39, 71, 72; Third Annual Report, 1913. Washington, 1911–1915. (From the Bureau.)

Universidad Nacional de la Plata, Anuario, No. 6. La Plata, 1915. (From the Universidad.)

University of Missouri, Engineering Experiment Station Series, vol. 1, Nos. 1–3; vol. ii, Nos. 1–3; vol. iii, Nos. 1–3; vol. iv, Nos. 1–4; Series Nos. 14 and 15. Columbia, 1910–1914. (From the University.)

Waltham Water Department, Forty-second Annual Report. Waltham, Mass., 1915. (From the Chief Engineer.)

BOOK NOTICES.

ELECTRICAL INSTRUMENTS IN THEORY AND PRACTICE, by W. H. F. Murdoch, B.Sc., and U. A. Oschwald, B.A. London: Whittaker & Company, 1915. 366 pages, illustrations, 12mo. Price, 10s. 6d.

As a careful technical compilation this book merits sincere commendation. Its scope is well suggested in the title, the emphasis being laid perhaps more upon the theoretical consideration of the various types of electrical measuring instruments. With an introductory historical summary, and after exposition of the subject of damping (so closely allied to the consideration of electrical measuring devices), the various types of instruments are successively treated. A very considerable portion of the book is devoted to electric supply meters, but we suspect that had the work been prepared primarily for the American technical reader rather than for the British, very much less space would have been devoted to electrolytic and other coulomb meters and very much more to watthour meters. The closing chapters are, respectively, on magnetic testing instruments and the "post-office" box. An admirable feature is found in the very complete references embodied directly in the text.

CHARLES PENROSE.

ANALYSIS OF MILK AND MILK PRODUCTS, by Henry Leffmann, M.D. Fourth edition, revised and enlarged. 115 pages, illustrations, 12mo. Philadelphia: P. Blakiston's Sons & Co., 1915. Price, $1.25.

The fourth edition of this work has just come from the press. As a guide for those engaged in the commercial and food-inspection laboratory it is well known and need not be reviewed at length.

It may be interesting, however, to note that in the present edition American investigations form the basis of many important processes, while in the first edition a considerable part of the material was derived from the publications of foreign workers.

HOUSEHOLD CHEMISTRY FOR THE USE OF STUDENTS IN THE HOUSEHOLD ARTS, by Hermann T. Vaulté, Ph.D., F.C.S. Easton, The Chemical Publishing Company, 1915. VI—233 pages. Small 8vo. Price, $1.50.

Though not stated on the title page, the preface indicates that the present issue is not the first edition of this work. The book is especially adapted to students taking a systematic course in the chemistry of food and household procedures. It is not intended as a popular essay. The author points out that household chemistry cannot be properly studied or taught without a good foundation of modern organic chemistry, and gives a comprehensive syllabus thereof for guidance.

The volume contains a large amount of information, both accurate and clearly expressed. Many illustrative experiments are described, and useful tables for conversion of units of different systems of measurement are included.

A capital defect of the book is the lack of an index. This should be remedied in the next edition.

HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

Chemical German.—An introduction to the study of German chemical literature, including rules in nomenclature, exercises for practice, and collection of extracts from writings of German chemists and other scientists, and a vocabulary of German chemical terms and others used in technical literature, by Francis C. Phillips, Professor of Chemistry in the University of Pittsburgh. Second edition. 252 pages, 8vo. Easton, Pa., Chemical Publishing Company, 1915. Price $2.

A Compend of Medical Chemistry, Inorganic and Organic. Including Urinary Analysis, by Henry Leffmann, A.M., M.D., Professor of Chemistry in the Woman's Medical College of Pennsylvania and in the Wagner Free Institute of Science. Sixth edition, revised. 241 pages, illustrations, 12mo. Philadelphia, P. Blakiston's Son & Company, no date. Price, $1.

Canada Department of Mines, Mines Branch: Products and By-products of Coal, by Edgar Stansfield, M.Sc., and F. E. Carter, B.Sc. Dr. Ing. 51 pages, tables, plates, 8vo. Ottawa, Government Printing Bureau, 1915.

Il Modulatore di Corrente del Dr. Francesco Morano, socio corrispondente. Estratto dagli Atti della Pontificia Accademia Romana dei Nuovi Lincei. 8 pages, plates, quarto. Roma, Institute Pio IX, 1915.

Latin American Monetary Systems and Exchange Conditions, by Joseph T. Cosby, Manager, Foreign Department, The National City Bank of New York. 31 pages, 8vo. New York, 1915.

U. S. Bureau of Mines: Bulletin 72, Occurrence of Explosive Gases in Coal Mines, by N. H. Darton. 248 pages, illustrations, plates, maps, 8vo. Technical Paper 83, The Buying and Selling of Ores and Metallurgical Products, by Charles H. Fueton. 42 pages, 8vo. Technical Paper 107, Production of Explosives in the United States during the Calendar Year 1914, with Notes on Coal Mine Accidents Due to Explosives, compiled by A. H. Fay. 16 pages, 8vo. Washington, Government Printing Office, 1915.

U. S. Department of Agriculture: Bulletin 246, Virtrified Brick Pavements for Country Roads, by Vernon M. Peirce. 38 pages, illustrations, plates, 8vo. Bulletin 257, Progress Reports Experiments in Dust Prevention and Road Preservation, 1914. 44 pages, 8vo. Washington, Government Printing Office, 1915.

Protection of the Eye from Harmful Radiation by Crookes's Glasses. (*Proc. Royal Society,* Series B, vol. 89, No. B 610, August 2, 1915.)—In order to protect the eye from damage by the radiation from luminous bodies it is necessary to remove as completely as possible the ultra-violet and infra-red rays, for these, while taking no part in the vision of external objects, do at the same time cause injury to the eye structures that absorb them. The visual rays, when present in excessive amount or when coming from a source in a position to form sharply-focussed images of filaments, etc., on the retina (eclipse blindness), also do harm and should therefore be reduced in intensity by neutral gray glasses. In the case of daylight the modifying glasses should be worn as spectacles; in the case of artificial illuminants they should form globes so as to limit the rays emitted to those useful for vision. For both purposes the glasses recently perfected by Sir William Crookes are ideal. A glass compound, as follows, was found most efficient in removing rays likely to injure the eye: Soda flux, 96.8.; ferrosoferic oxide, 2.85; carbon, 0.35. Its color is pale green, very pleasant to use, and the eye quickly becomes accustomed to the slight coloration. Color matches appear to be little affected by it.

On the Restraining Action of Sugar in Photographic Development. J. MALDIVEY. (*Comptes Rendus,* vol. 161, No. 4, July 26, 1915.)—Sugar added to a developer produces a restraining effect similar to that of the commonly used potassium bromide. The time of development of a normal metol-hydroquinone developer of 100 c.c. was increased from 5 seconds to 5 minutes by the addition of 60 grammes of sugar without fogging the clear parts of the plate or injuring the quality of the black deposit. Smaller quantities of sugar were found to produce correspondingly smaller increments in the time of development. Experiment indicates that this action is the result of a decreased rate of diffusion of the developer through the gelatin as the quantity of sugar is increased.

CURRENT TOPICS.

Gas Blowing Engines at the Steelton Plant of the Pennsylvania Steel Company. ANON. (*Metallurgical and Chemical Engineering,* vol, xiii, No. 8, August, 1915.)—The advance in the design of blast-furnace blowing equipment during the last five years has been very marked. The directions of progress stand out prominently. First, rotative speeds and piston speeds have been doubled; second, complications in valve gearing have been eliminated; and, third, automatic lubrication has been perfected to such an extent that the cost of attendance and repairs has been materially reduced. All three lines of progress are represented in the new gas blowing engines which the Mesta Machine Company recently installed at the plant of the Pennsylvania Steel Company in Steelton, Pa. These engines are the largest ever built in the United States; the gas cylinders are 46 inches in diameter, the air cylinders are 84 inches in diameter, and the stroke is 60 inches.

The modern gas blowing engine is just as reliable as the steam engine, and, in fact, more reliable. It can be started in less time and does not need to be warmed up. The Mesta gas blowing Engine at the Pennsylvania Steel Company's plant can be started and put on the furnace in less than one minute.

Preliminary Experiments on the Effect of Temperature Control on the Yield of Products in the Destructive Distillation of Hardwood. R. C. PALMER. (*Journal of Industrial and Engineering Chemistry,* vol. 7, No. 8, August, 1915.)—It is shown in small scale distillations that a lowering of the temperature of the process and decreasing the speed at which it takes place give marked increases in the yield of alcohol. Also the laboratory methods give much higher yields of acetic acid than those obtained commercially, but this yield is not greatly affected by varying the laboratory methods.

It is now seen that in applying these variations in methods of distilling on a much larger scale a change in the rate of distillation produces practically the same results in the yield of alcohol, while the actual temperature of the reaction is not shown to be of as great importance. If it could be shown that the formation of alcohol in the destructive distillation reaction and its probable secondary decomposition into methane and carbon dioxide in the presence of the hot charcoal is reversible, the increase in alcohol by control of the reaction, allowing an accumulation of the end products, would be easily explained.

If the products after formation are lost by decomposition, the greater stability of alcohol after formation as compared to acetic acid seems evident, since the large retort which probably involves many interreactions gives practically the same yields of alcohol as the small apparatus, while the acid yield is much less than the laboratory yield. Any process apparatus approaching the high laboratory production of acetic acid will probably have to involve some method of preventing the interreactions in the large apparatus.

It is not improbable that still higher yields than those given can be obtained in the commercial plant with the application of temperature control alone. Thoroughly air-seasoned wood would require appreciably less time to enter into the destructive distillation stage, thus giving a better opportunity to lengthen the period of slow reaction. The drying stage would also not require so high a temperature at the end, thus bringing all but the last portion of the reaction into a lower range of temperature.

These tests are considered as a preliminary indication of the results that may be obtained from the interpretation of temperature control. The study of this phase is being continued by larger runs comprising an entire plant. Other phases of directing the destructive distillation reaction of wood to produce maximum yields of products are being made by the United States Forest Products Laboratory.

Shrinkage and Time Effects in Reinforced Concrete. F. R. MCMILLAN. (*The University of Minnesota, Studies in Engineering,* No. 3, March, 1915.)—In the extensive investigations of the properties and behavior of reinforced concrete that have been made in recent years very little has been done in establishing the effects of loads sustained for long periods of time. This seems the more remarkable in view of the fact that a progressive sagging or cracking has been noticed in many structures. That these changes have not received more attention in the past is probably due to the suspicion of poor construction or inadequate design that is usually raised at the suggestion of such behavior, a suspicion unfortunately too often justified.

In the tests cited in this bulletin it has been found that certain changes do take place that are chargeable neither to poor construction nor inadequate design, but rather to the nature of the material itself—its tendency to shrink and yield under load. It is in recognition of the importance of these changes that this bulletin is brought forth at the present time; for, while no attempt is made even to suggest a solution to the problems presented by these shrinkage and time effects, it is felt that the facts presented are of sufficient importance to warrant their publication. With materials and mixtures used in these tests it is safe to predict a shrinkage of from three-fourths to one inch or more in 100 feet when exposed to the ordinary dry air of a heated building. The yielding of the concrete under compressive stress with time, a phenomenon similar to the yielding of ductile metals when stressed beyond the yield point, is greater as the unit stress is greater and seems to go on indefinitely. In these tests the deformation due to yielding was found to be from three to five times that produced immediately upon the application of the load.

A few of the possible results that may be looked for where these twin changes are in progress are suggested. The production of cracks in floors, ceilings, and partitions, even though in no sense indicating a structural weakness, is an undesirable feature. And in certain places with some types of structures or details cracks might leave the reinforcement accessible to moisture and thus prove a source of danger. Sagging of the structural framework may cause the bending of doors in positions, a feature that is both expensive and annoying. The tilting of columns by the unequal shrinkage in the different floors might be a source of high bending moments and column stress. But of far more importance than these may be mentioned the two following possible effects, both of which might in certain instances be of serious consequence:

First, the continued yielding of the upper fibres of a beam, coupled with the gradual breaking down of the concrete in tension, may result in a progressive destruction of the bond from the centre toward the supports, similar to that occurring with the progessive loading of a beam as shown by Mr. D. A. Abrams (*Bulletin 71, University of Illinois*). Also the drying out incident to the large shrinkage movement may assist in this destruction of the bond.

Second, the possibility of high stresses in the longitudinal steel of compression members seems to be the most important conclusion to be drawn from these tests. The time yielding of the concrete under stress, combined with the excessive shortening due to shrinkage, may result in deformations from five to fifteen times those expected from the ordinary calculations. In columns of the ordinary ratio of vertical steel in which no allowance has been made for spirals the resulting steel stress is probably well within the elastic limit, but in those columns designed on the assumption of large loads being carried by the hooping the steel stresses may approach dangerously near the yield point.

The Largest Hydraulic Motor. ANON. (*Scientific American,* vol. cxiii, No. 8, August 21, 1915.)—One of the striking exhibits to be seen at the Panama-Pacific Exposition is an immense hydraulic turbine motor, rated at 10,000 horse-power, which is in one of the several buildings for a California light and power company, and which is said to be the largest single discharge turbine ever built.

The casing is vertical, about 17 feet in diameter. The butterfly valve which regulates the admission of water to the turbine is 66 inches in diameter and requires a ten-horse-power motor to operate it. This turbine is built on the reaction principle and runs at a speed of 360 revolutions per minute under a head of 519 feet, and under these conditions from 400 to 465 cubic feet of water pass through the wheel every second. A spider at the centre, operated by the governor, controls the speed by regulating the opening of the guide vanes.

The electric generators installed in the plant are of a capacity of 12,500 kilowatt-volt-ampères, 6000 volts, three-phase, sixty cycles. Two of the above turbines drive each generator.

Joint Committee on Standards for Graphic Presentation. (*Journal of the American Society of Mechanical Engineers,* vol. 37, No. 8, August, 1915.)—As a result of invitations extended by the American Society of Mechanical Engineers, a number of associations of national scope have appointed representatives on a Joint Committee on Standards for Graphic Presentation. The committee is making a study of the methods used in different fields of endeavor for presenting statistical and quantitative data in graphic form. As civilization advances there is being brought to the attention of the average individual a constantly increasing volume of comparative figures and general data of a scientific, technical, and statistical nature. The graphic method permits the presentation of such figures and data with a great saving of time and also with more clearness than otherwise would be obtained. If simple and convenient standards can be found and made generally known, there will be possible a more universal use of graphic methods and a consequent gain to mankind because of the greater speed and accuracy with which complex information may be imparted and interpreted.

Percussive Electric Welding. ANON. (*Machinery* (London), vol. 6, No. 145, July, 1915.)—This method of electric welding was first applied to the welding of aluminum because that metal had given such trouble in soldering, especially when joining small wires. With the substitution of aluminum wire for copper wire which has taken place in the last few years, the need of a good means of joining aluminum has become urgent, and the percussive electric method was developed primarily for this purpose after a thorough investigation of the methods available. Percussive electric welding differs from the resistance method chiefly in the nature of the current used. For resistance electric welding, alternating current is used, whereas for percussive welding direct current is employed. It is possible to weld any two metals, whether alike or different, of high or low melting-points, or of unequal thermal conductivity, with aluminum; the oxide which covers the surface of the pieces welded prevents the metals from flowing together after the ends have been melted in the usual way. Large wires and rods of aluminum can be welded by melting the metal under the oxide film and then suddenly pushing the ends of the pieces together, breaking the oxide film and allowing the clean metal to flow together, but in small wires this practice is not feasible.

The apparatus employed is similar in construction to a pile-driver on a small scale. This is provided with one stationary and one movable wire grip or chuck. This " forge effect " and velocity can be varied independently by a separate adjustment of the length of drop and mass of the moving parts. The electric energy is supplied from a direct-current generator through an electrolytic condenser. At the instant of contact the condenser is discharged and the energy thus concentrated at the point of contact is sufficiently great to produce a perfect weld between the wires. The generation of heat is so localized, so sudden, and so intense that there is no time for an unequal heat conduction through the shanks of the wire, and the ends will be melted and even vaporized, whether the melting-point of the metal is high or low. All combinations of metals or alloys that have been tried will weld together, but the joints will not be permanent for such combinations as aluminum and tin or lead and iron.

Ionization Potentials of Mercury, Cadmium, and Zinc, and the Single- and Many-lined Spectra of These Elements. J. C. McLENNAN and J. P. HENDERSON. (*Proc. of the Royal Society,* Series A, vol. 91, No. A, 632, August 2, 1915.)—In a paper by Frank and Hertz in the *Physikalische Zeitschrift* these investigators have shown that the minimum energy required to ionize an atom of mercury is that acquired by an electron in passing through a fall of potential of 4.9 volts. These writers have also shown, in a later communication, that when heated mercury vapor is traversed by electrons possessing energy slightly above this amount the vapor is stimulated to the emission of the single spectral line $\lambda = 2536.72$ Å. U. This result constitutes a new and most interesting application of the quantum theory, for it will be seen that in the relation $Ve = hv$, where $h = 6.6 \times 10^{-27}$ erg sec., 4.9 volts is the potential fall which corresponds to the frequency v of the line $\lambda = 2536.75$ Å. U. If the relation just pointed out be applicable generally to all the elements, it follows that, if the vapor of an element can be shown to be capable of exhibiting a single-line spectrum, the frequency of this single spectral line may be used to deduce the minimum amount of energy required to ionize the atoms of that element.

With the object of establishing such a generalization if possible, some experiments were recently made by the writers, and it has been found that the vapors of cadmium and zinc as well as that of mercury can be stimulated to the emission of single-line spectra when traversed by electrons possessing the requisite amount of energy. With cadmium vapor the wave-length of the line constituting this single-line spectrum is $\lambda = 3260.17$ Å. U., while that of the single-line spectrum of zinc vapor is $\lambda = 3075.99$ Å. U. By the quantum theory it follows that the minimum ionizing potentials for cadmium and zinc vapors are, respectively, 3.74 volts and 3.96 volts.

A New Assay Balance. ANON. (*Metallurgical and Chemical Engineering,* vol. xiii, No. 8, August, 1915.)—An assay balance operated like a typewriter is a novel development in scientific instruments. This balance is the invention of Mr. Wilfrid Heusser, of Salt Lake City, Utah. The feature of the instrument that marks a distinct advance in balance construction is the method of handling the weights, placing them on or removing them from the pan hanger. By merely pressing one or more keys which are in front of and outside of the balance case, any weight or combination of weights can be deposited on the pan hanger. The weights themselves consist of perforated disks made of aluminum for the lighter and platinum for the heavier weights, as is usually the case. Normally each disk is carried by one of a series of upright posts with conical tops passing through a perforated horizontal frame which forms a part of the pan hanger. Each of these upright posts is operated by an individual key on a keyboard in front of the balance. By this means all handling of weights is avoided. An analytical balance embodying the Heusser construction as to truss beam and metallic case has also been developed.

The Relation between Uranium and Radium. F. SODDY and A. F. R. HITCHINS. (*Philosophical Magazine,* vol. 30, No. 176, August, 1915.)—The continuation of the measurements on the growth of radium from purified uranium preparations has shown an unmistakable increase in the rate of growth of radium in the case of the preparation containing three kilogrammes of uranium. The growth of radium appears to be proceeding according to the square of the time as theory requires, if ionium is the only long-lived intermediate member of the series. There is thus now for the first time direct experimental evidence that uranium is the ultimate parent of radium. The period of average life of ionium, calculated from this experiment, is about 100,000 years, assuming 2375 years as the period of radium.

An earlier preparation, containing 408 grammes of uranium, gives practically the same value for the period of ionium, calculated on the assumption that ionium was initially absent. The effect of any ionium initially present in the preparations would be to lengthen the period of ionium, but 100,000 years is probably not far from the actual period of average life.

PRESS OF
J. B. LIPPINCOTT COMPANY
PHILADELPHIA

JOURNAL
OF
THE FRANKLIN INSTITUTE
DEVOTED TO SCIENCE AND THE MECHANIC ARTS

VOL. CLXXX OCTOBER, 1915 No. 4

DEVELOPMENT AND RECENT ADVANCES OF THE TECHNO-GRAPHIC ARTS.*

BY

LOUIS EDWARD LEVY,
Photo-Chemist,
Member of the Institute.

AMONG the many new influences which are affecting our daily life in this modern time, when the arts are racing with the sciences in a rivalry for progress, not the least are those which are being exerted through the recent advances of the pictorial arts. Up to within the time of these developments all the various methods of pictorial representation could properly be included under the general designation of the Graphic Arts. A picture or design of any kind, on whatever substance it may be wrought, whether drawn with pencil, pen and ink, or crayon, or painted in oil or water colors, or engraved with cutting tools or etched with acids, is essentially a product of Graphic Art. Such are the delineations of animals and fishes found among the remnants of the cave men of the Stone Age of Europe, incised on bone with tools of chipped flint, perhaps a hundred thousand years ago; the designs indented on pottery by the Swiss lake dwellers

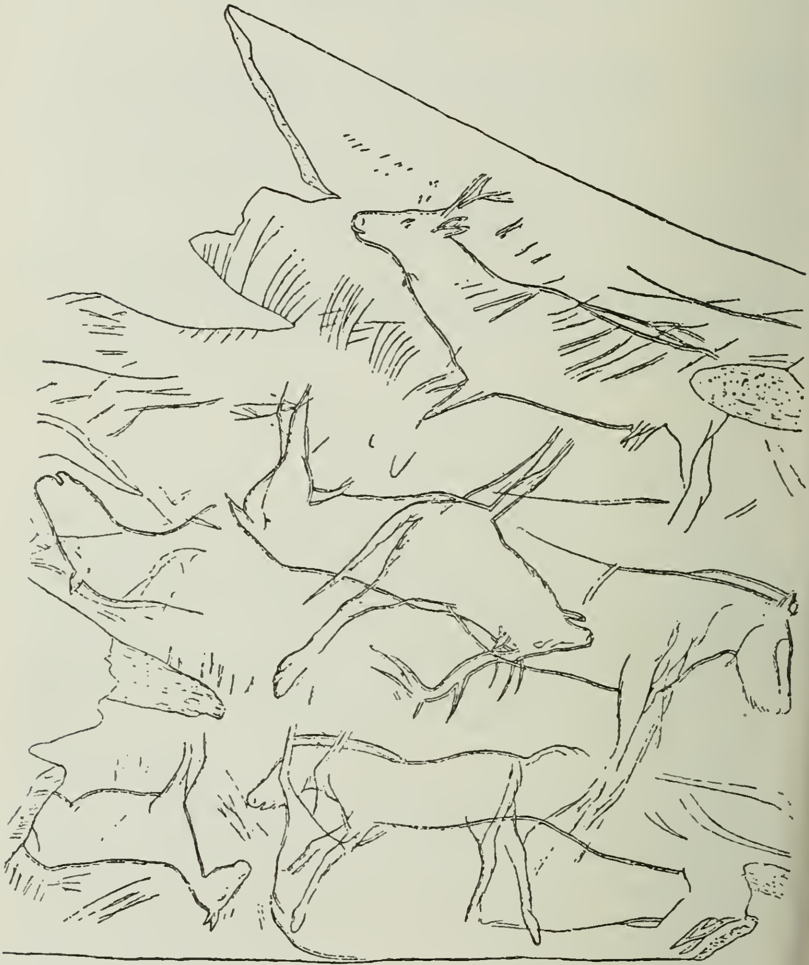
---

* Presented at the meeting of the Photographic Section held March 25, 1915.

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

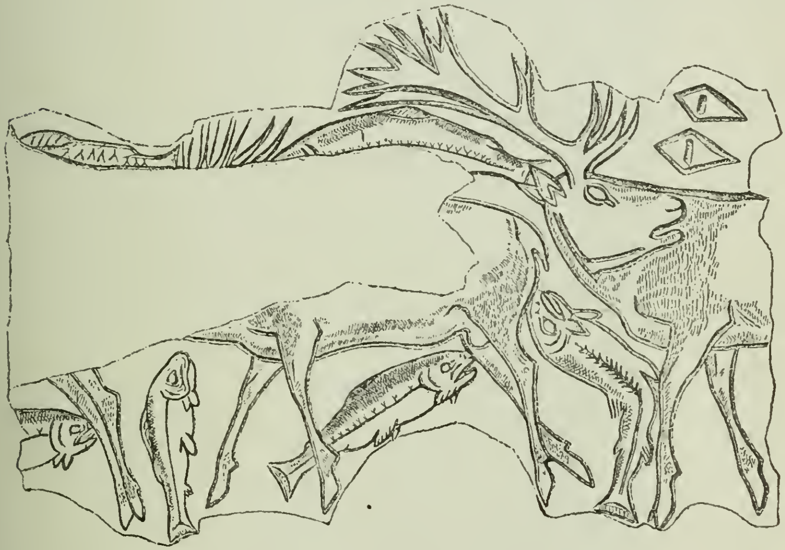
Copyright, 1915, by THE FRANKLIN INSTITUTE.

of the Bronze Age, some fifty thousand years ago; the colored pictures remaining on the walls of cave dwellings of the same period, and the similar productions of other primitive peoples in



Engravings on bone, mingled and superposed. Grotto of Lorthet, Hautes-Pyrénéés, France. (Éduard Piette, *Revue d' Anthropologie*, 1904.)

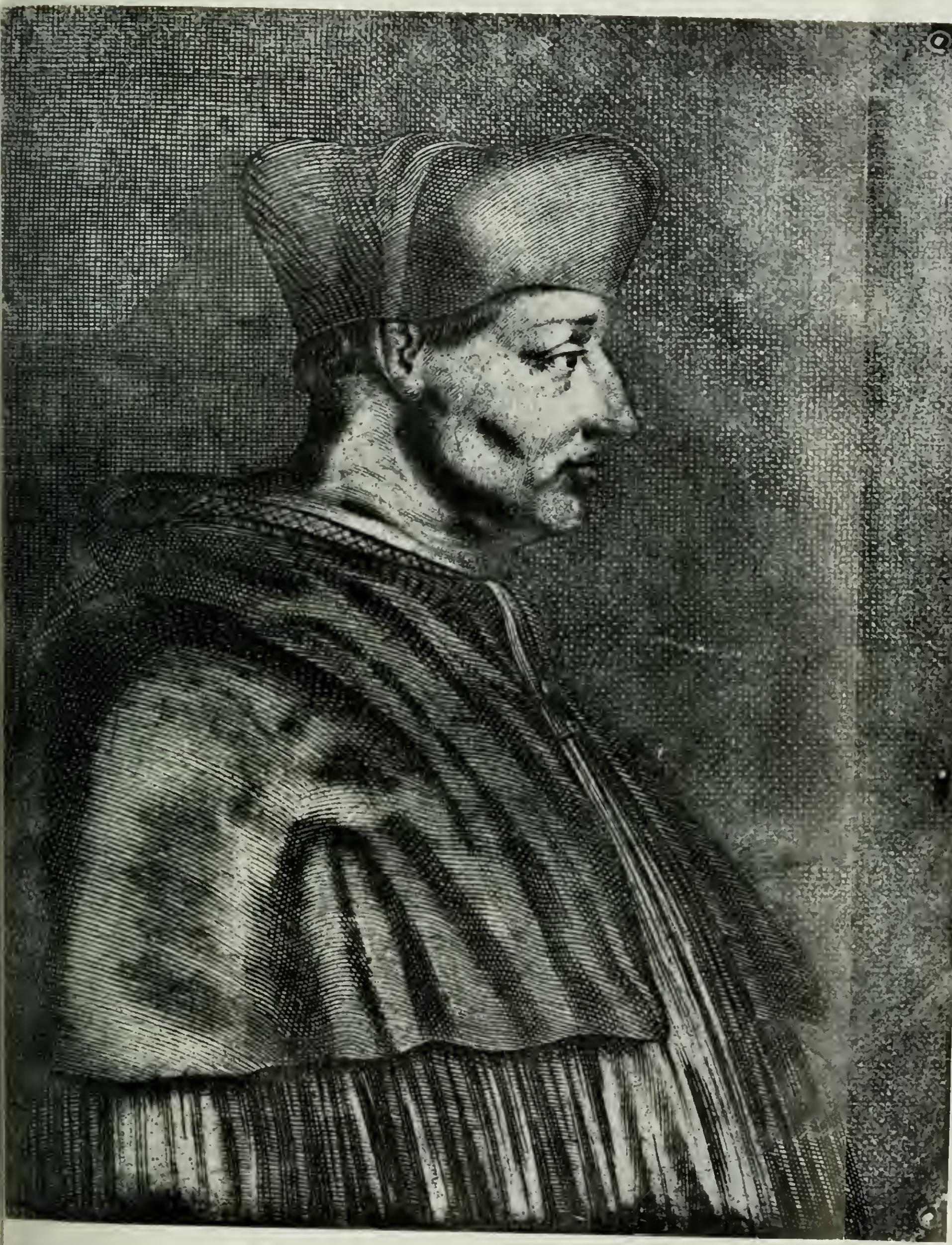
various regions of the globe through all the ages down to the present day. The decorative designs and pictorial representations traced in stone on the walls of temples and monuments that remain to us from ancient Egypt and Assyria, the engravings on stone and other material referred to in various passages of the Bible, the paintings on pottery and on walls that remain from the centuries of classic Greece and Rome, are all of them productions of Graphic Art, and so likewise are the similar remains of the early East Indians and of the pre-Columbian inhabitants of Mexico and Peru. Every such production being complete in itself and affording, moreover, not only a presentation of its subject but also a direct indication of the individuality, the mood of mind and the handicraft of the worker, is naturally to be classed as a product of what may be termed the Manual Graphic Art.



Engraving around piece of reindeer antler among remains in Grotto of Lorthet, Hautes-Pyrénées, France. (Eduard Piette, *Revue d' Anthropologie*, 1904.)

But when we come to consider such productions as are not complete in themselves, but require to be supplemented by the printing art, and by that means may be duplicated indefinitely, we must regard them as belonging in a separate category, which has been designated as the Reproductive Graphic Arts. Such are those of engraving on wood, copper, or steel, in which, however, the manual skill of the worker is still the sole and direct agency in the process of production. An indirect agent comes into play when acid is applied to engrave by etching a design which has been drawn by hand on a metal plate, but the skill of the draughtsman is still the essential factor in producing the result. Practically similar is the case in lithography where the design has first to be drawn by hand on the stone before the natural repulsion of fatty substances and water can be utilized in printing from it. Thus the arts of wood and copper plate or steel engraving, etching and lithography, appertain in principle to the Manual Graphic Arts. These various arts had reached a practically complete development when, about 1870, their field came to be invaded by the photo-engraving processes and the productions of the hand engravers began to be rivalled by those of the camera. This rivalry of the photographic with the manual graphic arts had its inception as far back as 1813, when an early French lithographer, Joseph Nicéphore Niépce, began working out a process of photo-engraving on lines pointed out by earlier discoveries of the light-sensitive properties of certain resinous gums. After a long series of experiments in this direction he succeeded, by about 1824, in obtaining a light-sensitive medium composed of asphaltum dissolved in a special oil. A film of this solution, flowed on plates of metal and dried, presented a substance which was so changed by the action of light that it became insoluble in the oil. On exposing the sensitized plate to light passing through a transparent paper print the part shielded by the print remained soluble, and when washed away by the solvent the design showed up on the bare metal. The undissolved film of asphaltum protected the plate sufficiently to permit the bare portions being etched, thus producing an intaglio photo-engraving. A specimen of these early productions, an etching on a plate of tin, made in 1825, has been preserved in the Niépce museum at his birthplace, Chalon-sur-Saône, and is doubtless the oldest production of a photographic process extant.

The asphaltum film was not sensitive enough to be practicable for use in the camera, but Niépce appears to have obtained with his crude instrument, the camera obscura of his day, by very prolonged exposures in brilliant sunlight, some pictures, both on glass and on metal plates, some of the latter silver plated. The pictures thus obtained were negatives, the thin asphaltum film being dissolved out in the development more or less as the exposure had affected it, the lights of the picture being thus represented by the dark undissolved portions of the film and the shadows by the white surface of the silver plate. To reverse the effect, Niépce subjected his finished plates to fumes of iodine,



eproduction of print from intaglio plate, photo-engraved by Niépce, 1824. Earliest photographic result extant.
n the print in National Museum, Washington, D. C. Negative by courtesy of Thos. W. Smillie, Honorary Custod-
Photographic Section.)

which darkened the silver surface by converting it into silver iodide. The asphaltum was then washed off with alcohol, leaving the picture showing black on white. In the course of these experiments Niépce noticed the change produced by light on the iodized silver surface of his plates and tried them in his camera. By prolonged exposure, yet much shorter than was necessary with his asphaltum method, he could obtain a visible picture on the plate, but it was not as satisfactory as the other, nor could he find a way of fixing it. While working to improve his method Niépce was brought in contact with the Parisian scene painter, Louis J. Daguerre, who was also trying to fix the image of the camera obscura and was experimenting to that end with phosphorescent substances. They combined their efforts in a partnership, Niépce contributing his process and Daguerre his improvement of the camera, but each continuing to work at his own home. Niépce kept on improving his process for photo-engraving purposes, while Daguerre sought some way of making it practicable for the camera. Two and a half years after they started in partnership,—that is, in July, 1833,—Niépce died, leaving his son Isidore to take his place. Daguerre kept on, but gradually abandoned the asphaltum film in his efforts to find some way to utilize the much greater light-sensitiveness of the iodized silver surface. At last, in 1837, after another four years' groping, both literally and metaphorically, in the dark, he accidentally discovered the secret that he sought. To get a visible picture on the iodized silver plate quite a long exposure was necessary, while with a shorter exposure nothing at all showed up on the plate. A number of such underexposed plates had been stacked away by Daguerre in a closet of his dark-room, to be later cleaned off for further use. On taking them out he was astonished to find a visible picture on the outermost plate. He at once surmised that something in the closet had brought about this effect. To find the active agent he proceeded to remove the contents of the closet one after another, leaving a plate to be worked upon after each removal. Having taken out everything that he could find and the effect still continuing to be repeated, Daguerre was at his wits' end when he discovered in the closet some globules of mercury that had remained unnoticed. Following this clue, he succeeded in working out the Daguerreotype process, which consists essentially in the application of mercury vapor to develop the latent picture on the iodized silver plate. The all-important factor in Daguerre's discovery was its revelation of the existence of an unseen photographic image that could be developed chemically.

After vainly trying for two years to get financial support in exploiting the invention, Daguerre and young Niépce concluded to offer it to the government, and to that end applied to the well-known scientist Arago. He at once recognized the importance of the new art and announced the discovery at a session of the Academy of Sciences on January 7, 1839. Through his influence and that of the Academy the French Government was induced to purchase the secret of the process and give it to the world. In July, 1839, a life pension of six thousand francs to Daguerre and of four thousand francs to Isidore Niépce was accorded by the French Government, and on August 19 the full details of the process were made public in a communication by Arago to the Academy.

At this very time another important discovery in the field of photographic chemistry was formally announced through the Royal Society of Scottish Artists by Mongo Ponton and published in the new *Philosophical Journal* of Edinburgh in May, 1839. Ponton had experimented on the lines indicated by the French chemist Vauquellin, who had discovered chromic acid in 1795 and had observed that the red color of chromate of silver became purple on exposure to light. Ponton found that paper impregnated with bichromate of potassium was very sensitive to light. By placing a translucent object on such sensitized paper and exposing it to light he produced a picture of the object in tones of brown, modulated according to the varying amount of light passing through the object, and could fix the picture by simply washing it in water.

At another juncture this discovery would have attracted universal attention, but the dramatic announcement and governmental publication of Daguerre's discovery produced such a furore among the general public, and in the scientific world as well, that not only did Ponton's discovery go unnoticed but the promising results in photo-engraving that had been obtained by Niépce were also entirely overlooked. A striking commentary on this condition is the fact that the Daguerreotype, notwithstanding its early improvement by Herschell, and later by Fizeau,

JOSEPH NICEPHORE NIÉPCE. 1765–1833.

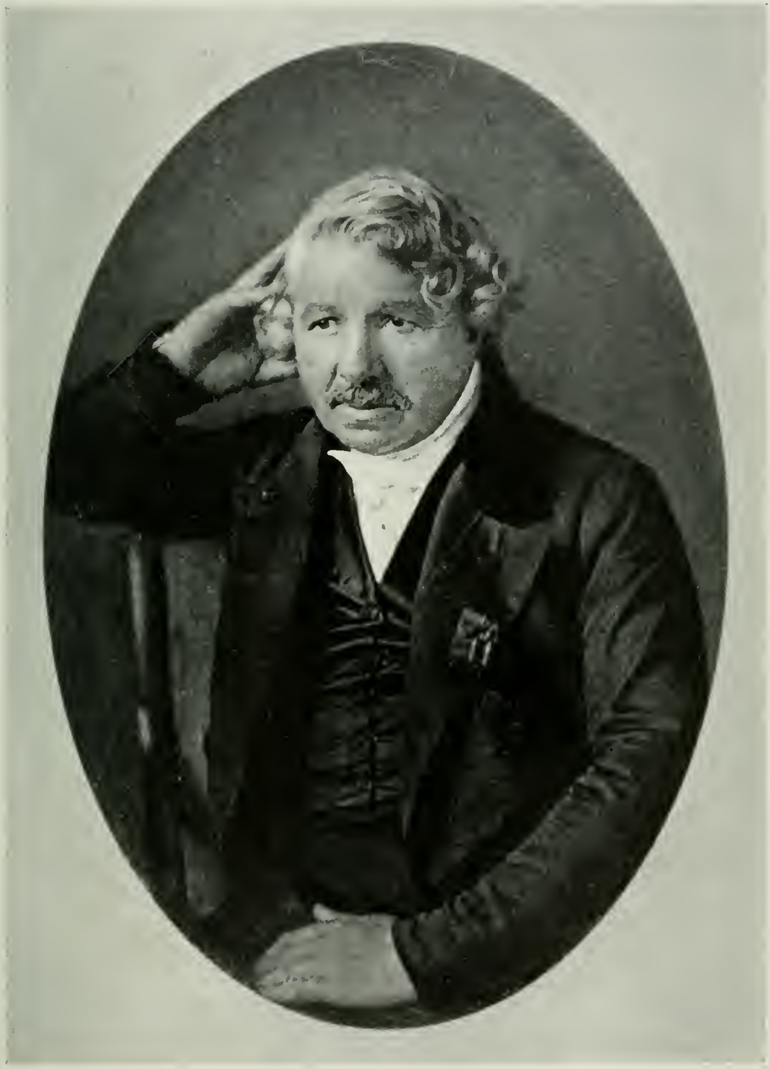
had before 1870 become a thing of the past, while Niépce's method, further developed and improved by his cousin, Niépce de St. Victor, about 1850, came gradually into extensive use and remains so to this day, and the photo-engraving processes based on Ponton's discovery have become universally applied.

Not until over ten years after that discovery was any notable effort made to develop its possibilities and then only in some modifications of Ponton's method of obtaining chromate prints on paper, by Becquerel in 1840 and Robert Hunt in 1843. Then again nothing was done with it for another nine years, but this time a long step forward was made by Fox Talbot, an English physicist, who had early devoted his efforts to researches in this field and had worked out a method of photography on paper sensitized with silver chloride. Talbot's experiments, following the direction of Ponton's work, led to the discovery that gelatine sensitized with bichromate of potash, when exposed to the action of light, became insoluble. Availing himself of this peculiarity, Talbot worked out a process of photo-engraving in intaglio and obtained a patent for it in October, 1854. The process consisted in flowing on the polished surface of a steel plate a solution of bichromated gelatine, letting this dry in the form of a thin film, exposing it to sunlight through a transparent positive, then washing out the unreduced bichromate with water and finally etching the plate through the unaffected portion of the film with chloride of platinum or of iron. Talbot conceived the idea of producing the effect of halftones by breaking them up into minute subdivisions of the engraving. This result he obtained by first exposing his sensitized plate under a screen of fine network, such as a piece of gauze, and then under a transparent positive of his subject, or, as an alternative, placing the screen between the positive and the sensitized plate and exposing them together. Talbot's intaglio etchings pointed the way to the subsequently developed process known as photogravure, and his application of the screen of gauze was the beginning of the halftone process. In his patent specifications he noted that the process could be applied for the production of photo-lithographs and of relief etchings on zinc, and called attention to the fact that even the thin film of gelatine on his steel plates, when immersed in water to wash out the unreduced bichromate, swelled sufficiently in the unexposed portions to produce a considerable effect of relief. Altogether, with the exception of special uses of the asphaltum process, Talbot's combination of the bichromate sensitizer with a gelatinous substance became the starting-point of all the modern photo-reproductive processes. The number of these, in their various modifications, has become legion, and still more numerous are the names by which they are sought to be identified. Even for the category in general several terms have come into use, such as photo-mechanical, photo-chemical, photo-reproductive arts, etc. The distinguishing feature of all these methods of graphic representation is that the skill of the worker plays only a directive part, the creative work being accomplished by the unconscious forces of nature through the application of scientific technology. It may therefore be permitted, if only for the sake of brevity, to denominate these methods of pictorial representation as the Techno-graphic Arts.

The development of these arts on the basis of chrome gelatine compounds proceeded in three principal directions: as a resist for etching, as a mould for electrotyping, and as a printing surface directly. Each of these possibilities presented numerous different ways of applying the principle involved, and it was not long before some of them began to be practised. Immediately after Talbot's publication Paul Pretsch, of Vienna, obtained an English patent for a process of applying the swelled gelatine film as a mould on which to produce electrotypes. By addition of silver iodide to his gelatine solution the swelled films produced a grain of varying fineness, according to the gradation of light and shade of the negatives or positives used for the exposure, thus furnishing photo-reproductions in halftone both in relief and in intaglio.

In the following year, 1855, Pretsch patented a method of producing by this process intaglio-engraved copper cylinders to be used for printing on textile fabrics, a premonition of the rotary photogravure process of the present day.

During these same years Alphonse Louis Poitevin, in Paris, who had previously worked out a method of turning daguerreotypes into intaglio engravings by galvanic etching, was working in the same direction as Pretsch, and in 1855 obtained a patent for a process similar to his. But his really important contribution to the progress of the Techno-graphic Arts was his method of printing direct from the exposed and developed chrome gelatine film on the principle of the lithographic process.



LOUIS JACQUES DAGUERRE, 1787–1851.
From a photograph copy of daguerreotype by Charles Meade, Paris, 1848. (*Snelling's Photographic and Fine Art Journal*, New York, January, 1855.)

He modified the chrome gelatine solution by adding albumen, gum arabic, and other colloidal substances, and after due exposure and washing out the unreduced bichromate from the film he passed over it a roller carrying a fatty ink which adhered only to those features of the plate that remained dry through having been affected by the light, and was rejected by the moistened ground. From the film thus inked up prints could be taken on paper and, if desired, transferred to lithographic stone and printed from that. So was started at once the practice of photo-lithography and of collotype printing. The former was afterwards, in 1859, simplified and improved by J. W. Osborne, in Melbourne, Australia, through his method of applying the chrome sensitizer to lithographic transfer paper direct, and further developed by numerous other workers of that period. Poitevin's collotype method, that of printing from the gelatine film direct, remained to be perfected by subsequent workers during the decade of the sixties, notably by Jacob Husnik in Prague and Joseph Albert in Munich.

Still another opening was made by Poitevin in the course of his fruitful activity through his application of chrome gelatine films colored with lamp-black or other pigments and dried on paper. By adding other ingredients to the gelatine solution the film became easily soluble in warm water, and was washed away in proportion as it had remained shielded in the exposure. This was the beginning of the pigment or carbon printing process which was afterward improved by John Pouncy in 1858 and practically perfected by J. W. Swan in 1864.

About the same time a new and very important application of the gelatine wash-out principle was made by Walter B. Woodbury through his process of printing with a pigmented glutinous ink. His method was to use the gelatine relief to produce an electrotype from which the glutinous ink, held in the graduated depths of the plate, was transferred to paper in corresponding gradations of quantity, thus producing pictures with a complete gradation of tone. In 1866 he modified the process by replacing the electrotype with a matrix obtained by pressing the dry and hard gelatine relief into sheet lead and transferring the glutinous ink from that. This process, known as the Woodburytype, came into extensive use and held its ground until gradually superseded by the collotype printing method.

In 1872 Woodbury patented a method of applying his process to the production of rolls from which to print in the cylinder or rotary press, thus reversing the method patented by Pretsch in 1855, by utilizing the wash-out instead of the swelled gelatine process for the purpose. Neither method, however, was found practicable.

The method of procuring intaglio photo-engravings in grain effect by etching the plate to modulated depth through the exposed gelatine film, which Talbot had devised at the very beginning of his work in 1854 and had patented as the first of his results, was gradually improved in its details, first by Talbot himself and afterwards, during the sixties, by several of his followers. Among these were a number of French workers, notably Dujardin and Rousselon, who, by applying the wash-out gelatine process devised by Poitevin and modified by Swan and Woodbury, obtained, both by electrotype and etching process, intaglio photo-engravings of a quality which left nothing to be desired and which made the Parisian art publishing house of Goupils famous. The method by etching was afterwards, about 1880, simplified by an Austrian worker, Carl Klic, but, through having been brought to its full development in France, it continues to be known everywhere by its French term, photogravure.

Yet another pioneer worker, Georg Scamoni, chief of the photographic section of the Russian Imperial Printing Office at St. Petersburg, added materially to the progress of the Techno-graphic Arts during this period. He worked out, about 1865, a method of photo-intaglio-reproduction by electrotyping on the metallic deposit which forms the image on the developed collodion plate, after first building this up to a sufficient relief by repeated redevelopment and intensification. His line reproductions by this process were used extensively for official documents and show a remarkable degree of delicacy of line and stipple.

From this time on the field of the Techno-graphic Arts rapidly widened out and the number of workers in it grew apace. I became one of these in Milwaukee in 1869 as an experimenter with swelled gelatine along the lines marked out by Pretsch, at the same time finding occasion to learn the methods and also the troubles of the collotype process. After a long interruption I began again in Baltimore in 1873, and in the following year

MONGO PONTON, 1804–1885.

obtained the facilities of David Bachrach's photographic gallery and also his coöperation in the working out of a new photo-electrotype process which, to distinguish it from its predecessors, we called the Levytype. Its essential features consisted in swelling the exposed chrome gelatine film in solution of silver nitrate, making this electrolytic by changing it into a sulphuret and electrotyping the mould thus produced. For this process we obtained a patent which was published in January, 1875.

In May of the same year a photo-electrotype process based on Poitevin's method of washing out the unexposed gelatine film instead of swelling it was patented by William Mumler, of Boston. His method was an adaptation of that of Fontaine, worked out in Paris in 1862, which consisted in washing out the unexposed portion of a thick chrome gelatine film and electrotyping the dried gelatine relief. This method found considerable application both in Europe and this country until superseded by the zinc etching process.

After working the swelled gelatine process commercially for about a year I came gradually to taking wax casts from the gelatine film and electrotype moulds from these, and from this it was but a step to using the wax casts for making plaster moulds in which to produce the relief plates in the form of stereotypes. My next step was taken in 1877 in the form of a removal to Philadelphia. Here, in 1880, I took up the zinc etching process which had long been practised in Europe, notably by Gillot in Paris, and which was then being used for the production of the *United States Patent Office Gazette.* In this process a photo-lithographic print was transferred to the surface of the polished zinc plate, the transfer strengthened with asphaltum powder melted into the ink and the plate then etched with nitric acid, leaving the surface protected by the inked design standing in relief. As the etching proceeded the vertical sides of the standing lines required to be protected against the action of the acid, and this was effected by applying additional ink and powder to the surface of the plate and then heating it to make the ink run down over the sides of the exposed lines. This was repeated usually seven or eight times until the etching had reached a sufficient depth for the requirements of the printing press. My experience with this method soon led me to the expedient of sensitizing the surface of the zinc instead of the paper and producing the design on the plate directly by exposure instead of indirectly by transfer. I next came to replace the inking-up and melting-down method of protecting the exposed lines of the etching by covering them instead with a shield of resinous powder brushed against the projecting lines and melted into place. This was done four times at right angles across the plate and proved to be sufficiently effective to permit the etching process to be completed in three or four stages instead of double that number. From here this four-way method of powdering became gradually disseminated through the craft and is known in Europe as the American method.

It was about this time, 1882, that the method of producing photo-engravings in halftone by means of an intervening screen of fine lines, first practised by Talbot in 1852 and gradually improved by a number of later workers, was brought to the point of successful application by Georg Meissenbach in Munich. Two other commercially applicable methods of producing halftone photo-engravings had previously been worked out, one by our subsequent fellow-member, Frederick E. Ives, in this city, and the other by Charles G. Petit in Paris. The former had begun in 1878 to obtain his results by inking up the surface of a modulated relief, obtained by the gelatine wash-out method from a transparent positive, and pressing this down on a sheet of paper the surface of which presented lines or stipples embossed in relief. The lights of the picture being low in the gelatine relief and the shadows high, the embossed paper would be pressed out more or less according to the gradations of light and shade of the subject as represented by the modulated relief of the gelatine film. The process was later modified by inking the surface of the embossed lines or stipples instead of the gelatine relief and bringing the inked surface in contact with a plaster cast from the gelatine. In either case the resulting black-and-white halftone effect was photographed to obtain a negative, from which in turn the final printing plate was produced in the form of a photo-electro or stereotype. Petit's process was similar in all respects, except that he inked the surface of the plaster cast and then cut across it in a ruling machine with a V-shaped tool. As this cut deepest into the raised portion of the relief representing the lights of the picture and left the depression more or less untouched, there was produced an effect of halftone which was

ALPHONS LOUIS POITEVIN, 1819–1882.

then photographically reproduced in the form of a printing plate. These methods of obtaining halftone effects by mechanical means had been brought into practical use on a commercial scale when the greater facility and more perfect results of the optical method as realized by Meissenbach became generally recognized.

Talbot used a mesh of gauze or bolting cloth to produce optically a reticulated surface of his photo-engravings, but in his patent he mentions glass plates covered with fine lines or a grain of opaque powder as applicable for the purpose. About 1857, when Pretsch's halftone method was being worked commercially in London, the attention of a number of experimenters reverted to Talbot's indications, and some progress in that direction was made. In December of that year a French patent was registered by A. J. Berchtold for a method of halftone reproduction with a screen of parallel lines ruled on glass. A metal plate sensitized with asphaltum was first exposed under an ordinary negative and then under the screen successively in cross directions with gradually-diminishing exposures. Various modifications of this method were afterwards worked out, one by C. J. Burnet in England in 1858, and another in this city by Frederick von Egloffstein, patented by him in 1865. The screens used by the latter were made for him under direction of the noted steel engraver, John Sartain, by his son Samuel, afterwards also a leading worker in that art and subsequently and for many years treasurer of The Franklin Institute.

A further improvement was made by the brothers E. and J. Bullock, in England, their patent of November 17, 1865, describing a method of halftone reproduction by first making a transparent positive, putting over this a screen of gauze or other material, and then making a negative from the two together. They also describe a method of photographing the negative through a screen of parallel lines ruled on glass and placed in front of the sensitive plate. From these negatives they produced photo-lithographs and also zinc etchings by the transfer process.

Among other methods of halftone reproduction patented at that period was one by Joseph Wilson Swan, described in his English patent of July 6, 1865. This was based on the solubility of the unexposed parts of a chrome gelatine film,—that is, on the wash-out principle,—but included covering the surface of the film before exposure with a ruling of insoluble cross lines, or producing these by transparent rulings on the positive or negative through which the exposure is made, and so retaining in the washed-out gelatine film a set of fine cross lines level with the surface. The dried gelatine relief was to be electrotyped and the plate printed as an intaglio or relief, according as a negative or positive had been used for the exposure. The method was unavailable, but pointed the way to possibilities which have latterly been realized in the so-called rotary photogravure process.

The earliest application of a photo-reproduction process in newspaper work was made in New York in 1873 in the production of the *Daily Graphic,* which was illustrated and printed by photo-lithography. Occasional supplements to this journal contained reproductions in halftone effects photo-lithographed by a method practised in New York by Leggo & Desbarets, including the application of a film of ruled lines between the negative and the sensitive plate. Some years later Swan obtained an English patent in which he describes a method of producing halftone negatives through a screen, the lines placed either before a transparent positive or before the sensitized plate in the camera, and turning the screen at an angle between each of several partial exposures of the plate. In 1882 the expedient of interrupted exposure through a screen of parallel lines was put into effective practice by Meissenbach through turning the screen only once—and that at a right angle—and this, combined with the improved process of zinc etching, which had come into use by that time, afforded results which marked an important era in the progress of the Techno-graphic Arts. I myself was at that time working to obtain halftone reproductions in grain effects by means of transfers from coarse-grained gelatine prints, and had put in a collotype press for the purpose. But the uncertainty of gelatine effects and the greater simplicity of the screen method pointed to the latter as the true direction of further effort. Meissenbach had transferred the screen of lines from between the negative and the sensitized metal plate to a more rational place between the copy and the camera. It remained to take the decisive step of transferring it back to a place within the camera in front of the sensitive plate, and this I soon concluded to do—not sooner, perhaps, than Meissenbach and others in Europe had done the same.

For a time the screen of single parallel lines extending diagonally across the plate and turned half way round during the

WILLIAM HENRY FOX TALBOT, 1800–1877.

exposure continued in use, though the application of a cross-lined screen with uninterrupted exposure readily suggested itself. I got practical results with such screens, composed of wire bolting cloth, as early as 1883, but the possibility of obtaining varied halftone effects with the single-line screen by varying the proportions of the divided exposure, coupled with the difficulty of getting a sufficiently perfect cross-line screen of any size, kept the single-line screens in use. These were generally produced by photographing a sheet of parallel lines printed from a steel plate or a lithographic stone ruled by machine, reducing the size to get closer rulings. But the clouding of the open lines through halation, which left those lines most transparent in the middle and gradually less so towards their edges, though apparently a desirable feature, proved in practice to be a hindrance, and even where the lines were cleared as much as possible these photographed screens kept out so much light as to necessitate a considerably prolonged exposure, and when doubled to make a cross-line screen the difficulty was correspondingly increased. The way forward was manifestly through a proper ruling on glass. To get this crosswise and to overcome the diffraction effect of surface rulings I conceived the idea of etching the ruled lines with hydrofluoric acid and blackening the depressions, which would give a theoretically perfect screen and a correspondingly perfect halftone reproduction. Small screens of this kind were put to use in 1887, and with the collaboration of my brother Max in this direction the idea was finally realized in full and patented by us in 1891.

Following these successive improvements of the halftone process, its uses and applications advanced by leaps and bounds. As early as 1890, in an article on this subject in the *American Annual of Photography* for that year, I found occasion to remark as follows:

"The influence of the halftone process in the dissemination of intelligence is already making itself felt in the pages of standard and current publications everywhere, and its value as an adjunct in raising the standard of art culture and of artistic appreciation is commensurate with its almost limitless possibilities. It is the graphic method of the future, combining as it does, in a higher degree than any other, the illustrative and the æsthetic elements of art."

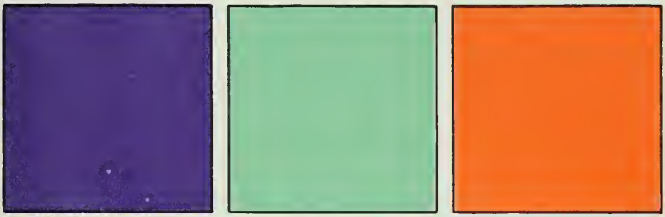
During the quarter century which has since elapsed two further advances of striking importance have been made in the application of halftone photo-engraving; namely, the three-color printing process and that of rotary photogravure.

The production of pictures in colors had become the special province of lithography, although for many purposes the greater rapidity and corresponding economy of printing from relief plates made this latter method preferable. In either case a considerable number of successive printings, in different colors from as many different forms, is necessary, and printers and lithographers working with colors have sought to reduce the number as far as possible. To some extent this could be done by printing one color over another to produce a third, and, by gradations of tone in each, bring about various tints of the combined colors. By combining in this way the three principal colors, red, yellow, and blue, a wide range of other colors and tints can be produced, the effect depending on the degree of skill with which the engraver or lithographic draughtsman works up the three different printing forms which make up the combination.

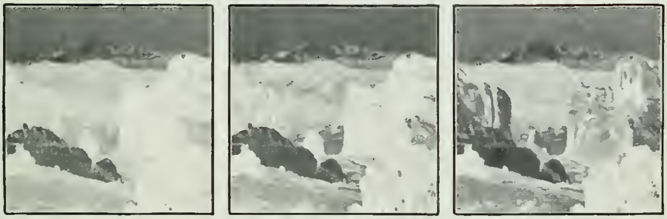
A very important advance in the production of color effects by photo-lithography is that known as the Polychrome process, patented in Europe by Henri J. Burger of Zurich, in 1897. In this process the printing forms, instead of being worked out by the lithographic draughtsman, are produced photographically, the negative of the subject, with all but the desired features stopped out, being used for one or two of the color forms, and transparent positives from the same negative, with the correlative features stopped out, being used for the other colors. A key plate from the original negative completes the effect. An essential feature of the polychrome method is the use of the asphaltum process to produce the printing form on the stone, the developed film presenting a very fine grain, corresponding with the gradations of the negative or positive applied in the exposure, and through which the stone is etched in preparation for the printing. This method is capable of producing effects of a high artistic quality and is especially applicable for subjects of large dimensions.

With the development of the halftone process the way was open for the production of relief-plate engraving by the three-color process of photography which had already previously been utilized, but only within the limitations of collotype and photo-

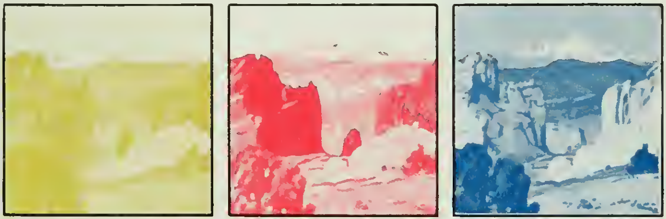
THE THREE-COLOR PROCESS



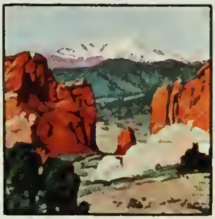
Glass Color Screens, Through Each of Which a Separate Negative Is Produced



Negatives Produced by Photographing Through the Respective Screens Above



Positive Reproductions of Above Negatives Printed in Colors Complementary to the Respective Screens



The Three Plates Printed Over Each Other

lithographic printing. In this process all the colors of an object are registered photographically on three separate negatives. One of these is photographed through a transparent screen colored orange red, so as to permit the sensitized plate to be affected only by those rays of light from the object which are contained in that part of the spectrum which includes the red and extends over the yellow to the green; the second is made through a filter screen colored green, so as to permit the passage of only the rays extending from the edge of the yellow over green to blue; and the third negative is made through a screen colored violet blue, which permits only those rays which are included in the remaining part of the spectrum to filter through and leave their impress on the sensitized plate.

These three color-separation negatives, together, therefore contain, in monotone, the effect of all the different colors of the object in all their various gradations of intensity; that is, in all the various tints of the respective colors from light color to full. By making these negatives through a halftone screen at the same time that the light is filtered through the color screen, they are made directly available to produce the print on metal for the etching process. Otherwise, it is necessary to make from each negative a print or transparent positive from which, in turn, the half-tone negative is made. The former is known as the direct, the latter as the indirect method.

As in each case the gradations of colored light are represented by corresponding gradations of darks in the halftone negative and, of course, by the reverse effect in the positive print from the halftone etching, it follows that the latter represents the colors and tints which were kept out by the color filter through which the negative had been made; that is, those complementary to that of the filter used. Accordingly the half-tone plate from the red filter negative is to be printed in blue-green, that from the green filter in magenta red, and that from the blue filter in yellow. By printing these one over another the effect of the combination is to reproduce, at least approximately, all the various colors and tints of the original. A supplementary plate, reproduced from a negative which represents the object as a whole, may be printed over the color combination in a neutral gray to make up for the shortcomings not only of the process itself but particularly of the printing inks in reproducing the true colors.

The technology of this process, like that of photography in general, may be traced back to the rise of modern chemistry in the seventeenth century, but its actual beginning is to be found in Newton's discovery in 1672, that white light is composed of rays showing all the colors of the rainbow, and that these in turn can be recombined into white light. This led to the idea of producing the entire range of colors by spreading one transparent pigment over another successively. Experiments in this direction, made by J. C. LeBlon, a copper plate engraver in Rome, from about 1720 to the time of his death in Paris in 1741, led to the conclusion that red, yellow, and blue were primary colors which, by proper combination, could be made to produce all the others. The researches of Thomas Young, published in 1807, afforded physiological reasons for assuming that the colors which could be so combined were red, green, and violet. Young's theory was subsequently strengthened by the investigations of Helmholz from 1856 to 1866, and practically confirmed by those of Clerk Maxwell during the same period. The latter, in 1861, was the first to actually demonstrate the possibility of obtaining a registry of all the colors of an object on three separate negatives photographed through three different color-filter screens, and thereby laid the foundation of the process of three-color photography.

The earliest practical application of this process was made about 1868–69 by two French photographers, Ducos du Hauron and Charles Cros, who, working independently, both produced their results by making with the gelatine wash-out process three pigment prints from the color-separation negatives, respectively in yellow, red, and blue, and laying these one over the other to complete the picture. A modification of this method was to make the gelatine wash-out prints in colorless films and color these with suitable dyes before combining them.

But much remained to be done to make three-color photography commercially available, principally toward increasing the sensitiveness of the photographic plate, especially to the less active color rays of the spectrum. A great advance in this direction was made by H. W. Vogel, in Berlin, in 1873, through his discovery of the efficacy of coloring the photographic plate with various dyes to increase its color sensitiveness. This opened a new field of investigation which was next explored by Cros, du

Hauron and Becquerel in Paris and at the same time by a noted member of this Institute, M. Carey Lea, in this city. Progress in this direction was made anew by Vogel in 1885, and greatly furthered by our distinguished fellow-member, Frederick E. Ives, in 1888. These advances brought three-color photography to a point where it was finding practical application in lithographic and collotypic printing, when the improvement of halftone engraving through the introduction of the engraved cross-line screen opened to the three-color process the far wider field of the typographic press.

More recently the halftone process has found a new application in the form of the engraving and printing method known as rotary photogravure. In this process an intaglio photo-engraving, instead of being produced on a flat plate to be printed from by the slow method of the copper-plate or steel-plate press, is engraved by the cross-line method on a copper cylinder and printed from by the far more rapid means of the rotary press. For such printing the ordinary method of inking intaglio plates, which consists of forcing thick printer's ink into the hollows of the engraving and wiping off the surface before each impression, is impracticable. Instead of that, the inking is done by the method used in the printing of textile fabrics and wall-paper from copper rolls. This is effected by covering the surface of the engraved cylinder with a thin liquid ink of any desired color, which flows into the hollows of the engraving and is cleared from the surface by means of a scraper, known in the trade as a " doctor," leaving the ink in the hollows, from which it is taken up by the paper as it passes over the rotating cylinder under pressure from above.

Like all intaglio engraving and printing processes, the rotary photogravure method is capable of producing very fine effects, but, as the engraving must be cylindrical and requires a special method of printing, the process cannot be economically applied except where large editions are to be printed off, and it is consequently available mainly for use in the pages of illustrated periodicals of large circulation and for pictorial supplements to daily newspapers.

A method of engraving copper cylinders by the halftone process and applying them in the manner of textile printing was patented in Germany in 1904 by Eduard Mertens and developed by him for newspaper illustration in Freiburg in 1910. The engraving on the copper cylinder was produced as a halftone intaglio, in a manner similar to that on flat plates which I took occasion to bring before the Institute in 1892 and which is described in the JOURNAL of September of that year. By that process the gradations of light and shade are made up, as in halftone relief plates, by differences in the size of the dots and stipples produced by the cross-line screen, the intervening depressions, which receive the printing ink, being of uniform depth. In the grain photogravure process, on the contrary, the gradations of light and shade are produced by graduated depths of the engraving, which accordingly receive the ink in quantity varying with the depth instead of the breadth of the depression. Such plates require that the depressions be produced with a roughened or grained bottom so as to hold the ink, which, for that purpose, must be quite thick, and the textile printing method with thin ink cannot therefore be applied with them.

A method of overcoming this obstacle appears to have been worked out in London some time before 1900 and employed there commercially, in great secrecy, under the name of " Rembrandt " intaglio printing. The main features of this process, which gradually came into general use, were the production of the engraving on the cylinder as an intaglio etching with graduated depths, and producing this intaglio with a network of thin cross lines. These are provided for the purpose of holding the scraper or " doctor " on the surface of the intaglio, the liquid ink left by the scraper being held in the interstices between the crossings in quantity varying with the depth of the etching. The result is produced by exposing a wash-out gelatine film under a transparent positive of the picture, then exposing it again under a line screen, but using one of transparent cross lines instead of the normal halftone screen of opaque cross lines. The exposed film is then placed on the copper cylinder and there developed by washing out, or it may be developed on paper like a carbon print and transferred from that to the surface of the copper. The metal is then etched with iron perchloride, which penetrates the dry film more or less, according to the varying thickness of the undissolved gelatine, and bites into the surface to correspondingly varying depths. The cross lines of undissolved gelatine, resulting from the exposure through the transparent screen, shield the metal surface uniformly, leaving a corresponding network of thin cross lines in the etching.

Thus the method of producing photo intaglio engravings with surface cross lines, which Swan patented in 1865 and which proved impracticable, and the two early methods of producing photo-engraved printing rollers, that of Pretsch in 1855 and that of Woodbury in 1872, which also were impracticable, have been replaced by methods which recent advances in the art have made effective for the purpose.

Among the many other new applications of techno-graphic art which have latterly been developed, at least one more calls for consideration; namely, the offset printing process. This is virtually a new way of printing, not of engraving, but it falls properly within our present purview, if only because, in connection with this newest method of printing, a new use has been found for the oldest method of photographic reproduction, Niépce's asphaltum process of 1824.

In the offset printing process the impression on the paper is not made directly from the form itself, but indirectly from a print of the form on an intervening medium, from which, in turn, it is offset on the paper under pressure; hence the name of the process. Any printing surface from which prints can be obtained in any of the usual ways is applicable for the purpose.

Offset printing is really a development of the old process by which decorative designs printed on paper are transferred to pottery. Since about 1880 this method of transferring by offset has been in use for the printing of lettering or decorative designs on tin plates or other rigid surfaces, usually through lithography. Essentially the method consists of printing the inked form on the surface of a comparatively soft cylinder, usually a covering of soft rubber on a metal roll, and from that to the material, paper, fabric, metal, or what-not, which is to finally receive it. The printing on metal plates is usually effected in the flat press, the plates taking the place of the printing form on the bed of the press and the form in turn being replaced by the soft impression cylinder, which first receives the print from a cylindrical printing form, stereo- or electrotype, and then offsets it on the metal surface.

From about 1890 this process began to be applied to printing on paper, principally by lithographic transfers in cylinder presses adapted for the purpose. A notable advance in offset printing was made by Ivan Orloff at the Russian Imperial Printing Office, in St. Petersburg, through his invention of a press specially designed for the purpose and patented in 1897. This press, as exhibited at the Paris Exposition of 1900, was adapted for printing in colors from relief plates fixed on several cylinders, the successive impressions from which were first printed in registry on a cylinder of soft rubber and finally transferred from that to paper. But it is only during the last ten years, since the offset press came to be materially improved, that this method of printing has come largely into commercial use. During the same period the field of offset printing has been extended through the use of halftone reproductions applied from photo-lithographs or etched plates and latterly from photographic prints on zinc plates by the asphaltum process. This affords a greater delicacy of impression in being printed on the rubber cylinder, and is giving the offset process increasing importance among the techno-graphic arts.

Many, indeed, and widely ramifying have been the advances of the pictorial and printing arts during these recent years, and never before have they been applied so universally as now. They have become, more than ever before, not only an expression of the culture of the time, but the most powerful agency of its further progress. The great educational movement of our modern day, which is so fast changing the complexion of the social structure, has its most efficient vehicle in the printing press, and through no other influence has that efficiency been so greatly reinforced as by the development and recent advances of the techno-graphic arts.

BIBLIOGRAPHY.

The literature bearing on the development of the techno-graphic arts is widely spread through publications of scientific societies, the records of patent offices, the pages of numerous technical periodicals and of a long list of special treatises and collated works, a citation of which would surpass the limitations of the foregoing review. The "History of Photography" (*Geschichte der Photographie*) by Dr. Josef M. Eder, the eminent director of the Royal-Imperial Institute of the Graphic Arts, in Vienna, published in 1905, and forming the first volume of his "Complete Handbook of Photography" (*Ausfürliches Handbuch der Photographie*), contains numerous references to the original data of the subject, and to this the present writer is largely indebted.

THE ESTABLISHMENT OF PHOTOMETRY ON A PHYSICAL BASIS.*

BY

HERBERT E. IVES, Ph.D.,

Physical Laboratory, The United Gas Improvement Company,
Member of the Institute.

SYNOPSIS.

1. Introduction.
2. The basic idea of the physical photometer.
3. The method of visual colored light photometry.
4. The development of practical physical photometers.
5. The question of luminous efficiency.
6. The mechanical equivalent of light.
7. The fundamental standard of light.
8. Discussion.
9. Definitions.
10. Summary of work accomplished, and statement of that still remaining.

1. Introduction.

When we "turn on" an electric lamp we supply it with power, and we get (among other things) light. The power supplied we measure with simple instruments which indicate by the position of a pointer on a scale. Our unit, the watt, is directly and simply connected with the fundamental units of length, mass, and time.

---

* This paper was prepared, on invitation, for the International Electrical Congress at San Francisco. On the abandonment of the Congress publication in this JOURNAL was arranged for.

The practical physical photometer described under section 4 is clearly the same instrument as that described by W. W. Coblentz in the September issue of this JOURNAL. Every detail of this photometer was worked out by the writer and Mr. E. F. Kingsbury. It was exhibited and described to Dr. Coblentz on the occasion of his two visits to our laboratory during the past year. It has been shown as well to numerous other visitors, for several of whom incandescent lamps and colored glasses have been measured. The device was described before the American Physical Society at its New York meeting, October, 1914, and the complete description has been in the hands of its journal, *The Physical Review,* since April. Its use forms one of the recommendations made by the writer to the Illuminating Engineering Society (*Trans. I. E. S.,* vol. x, No. 4, p. 315, June 10, 1915) which are now under study at the Bureau of Standards on behalf of that society. H. E. I.

When we undertake the measurement of the light produced the procedure is not so direct. We have recourse to a device called a photometer, which indicates by other means than the automatically moving pointer so popular in many kinds of measurement. In the photometer are comprised another lamp, means for varying the amount of light from that lamp, and a "photometric field," which is an optical arrangement specially designed to use the light-sensitive part of the apparatus—the human eye—at its maximum sensitiveness. The movement of the pointer is done by the human hand, according to the dictation of the eye. When its position is read upon the scale of the instrument a measurement is obtained which, under a certain definite condition, compares favorably in accuracy with other kinds of measurement. This condition is that the lights under comparison are of the same color, as in the case of a gas flame and a pentane lamp. When, however, we depart from this condition of similarity of color the same accuracy cannot be claimed; we enter what is still, in fact, debatable ground in photometry.

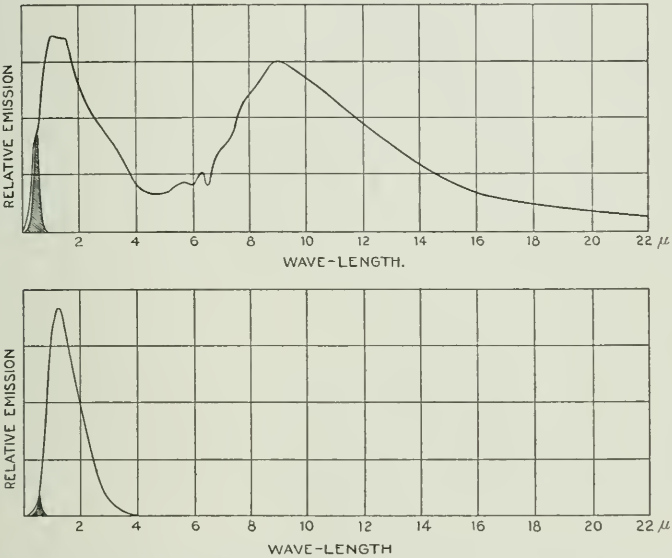
Having made a measurement under those restricting conditions where satisfactory accuracy is possible, we express the result in a unit—the candle—which, while definite and carefully maintained, has no simple or direct connection with the excellent system of units now in use in other branches of physics and engineering. In short, as the current goes past the switch its measurement passes into a territory but partly developed and still under the sway of the inconvenient and the arbitrary.

The goal of physical photometry is to make the measurement of light as simple as the measurement of power, and to express the result in the same unit—the watt.

The attainment of this goal is possible only through the coördination of extensive investigations in two separate branches of science; namely, physics and physiological optics. It is the object of this paper to bring together in one place such a summary of these investigations as will give a clear idea of the success thus far achieved in placing photometry on a physical basis.

We shall first outline the basic idea of the physical photometer. Then a review will be made of the investigations in visual colored light photometry whose completion is a necessary preliminary to successful physical photometry. Considerable space will then be given to a description of the actual development and use of satisfactory physical light-measuring instruments. After this an apparent digression will be made to the study of physical means of evaluating the efficiency of light production. Through this we shall arrive at an idea of the relationship between what the physical photometer and the visual photometer measure.

FIG. 1.



Complete spectra of Welsbach mantle (upper diagram) and tungsten lamp (lower diagram).
Small cross-hatched areas—luminous flux.
Ratio of cross-hatched areas to total areas=radiant luminous efficiencies.

The numerical factor connecting the present unit and the watt will be discussed under the head of "The Mechanical Equivalent of Light." The proposal that the watt is the rational unit of luminous flux then follows.

2. *The basic idea of the physical photometer.*

Of the power supplied to a light source, part is dissipated as heat by conduction through burner, leading-in wires, or supports. Part is dissipated by convection of heat through the atmosphere surrounding the light source. A third part is dissipated in the form of radiant heat or electromagnetic waves through the ether. In all of these forms the power is measured in the same unit, the watt.

We are primarily concerned with the radiated power, for it is a portion of that which we measure as objective light, and express at present in a unit called the lumen, derived from the candle.

The radiation from a light source, when passed through a dispersing apparatus, such as a prism, is resolved into a spectrum. In Fig. 1 are shown in diagrammatic form the complete spectra of two representative illuminants, a Welsbach mantle and a tungsten lamp. The radiation consists of a large portion of invisible and a small portion of visible rays. The visible radiations have widely varying capacities to illuminate or to rouse the sensation of light in the brain. These varying capacities are roughly represented by the small curves enclosed in the visible parts of the spectra. They represent the relative brightnesses of the different parts of the visible spectra of these illuminants.

The basic idea of the physical photometer is readily grasped from this figure. It must be an instrument capable of measuring radiation, and it must respond to each of the spectral radiations in proportion to their luminosity; that is, it must not respond at all to the invisible radiations, it must respond most to the radiations at the middle of the visible spectrum, in the yellow-green, and progressively less toward the red and blue at each end.

It is at once clear that the foundation of the physical photometer is a knowledge of what is called the luminosity curve of the spectrum. If the physical photometer measures the different parts of the spectrum in proper relative value, it will measure correctly lights built up out of the spectrum; that is, all lights. The method of determining this luminosity curve must now be outlined.

Before proceeding to this the problem of the physical photometer may be made clearer by a comparison with the human eye. Now the eye behaves in respect to the luminosity factor of radiation exactly as though it consisted of a retina sensitive to all kinds of radiation, before which is interposed a colored absorbing medium opaque to the greater part of the radiation spectrum, and most transparent to the middle of what we call the visible spectrum. It is the task of the constructor of the physical photometer to substitute for the retina some other medium sensitive to radiation, and to place before it an absorbing medium which shall transmit the different radiations in the same way as the hypothetical medium over the retina. This absorbing medium may be pictured as a spectrum template, through which the various radiations pass, each being reduced in passage to its appropriate value as light.

3. *The method of visual colored light photometry.*

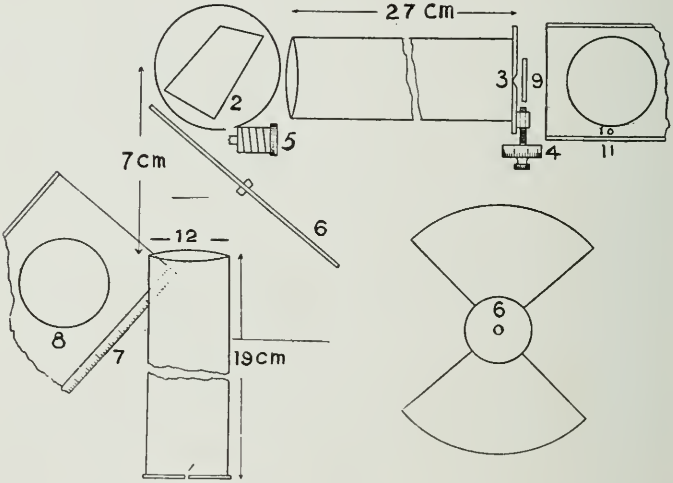
The determination of the spectrum light template or luminosity curve is a problem capable of solution only after a method is developed for evaluating the luminosities of radiations of different colors. The simple comparison of two radiations as in ordinary photometry becomes inexact and unsatisfactory immediately the radiations are different in color. The difficulties of colored light photometry are several. It is, first of all, impossible for the eye to appreciate anything save exact similarity or lack of that. It can not, for instance, tell how many times one surface is brighter than another. Now when the lights to be compared are different in color the condition of exact similarity can never be attained. Consequently it is difficult to decide when two colored areas are equally bright. Many observations, extending over an extended interval of time, are necessary. Another difficulty lies in the fact that the relative luminosities of different colors change with the intensity. Blue becomes relatively brighter, red darker, as the illumination is decreased. Still another difficulty is met, due to the variation of relative brightness with the size of the areas viewed.

These difficulties are met by the individual observer. When we are interested in more than one individual, we meet with difficulties due to differences between individuals. No two people see colors of exactly the same relative brightness, and their differences range all the way from trivial ones to the serious ones accompanying color-blindness. No matter what method of colored light photometry is used, it is essential that a sufficient number of observers be employed so that the results may be truly average. We have recently found that the number necessary to establish an average value is about fifty, none of the fifty having any marked abnormalities of color vision.

We therefore find in the difficulties of colored light photometry some of the greatest obstacles to be surmounted before physical photometry may be realized. But at the same time we find a weighty additional call for such an instrument. The services rendered by an instrument which measured differently colored lights as easily as ones of the same color and could as well embody the characteristics of the average eye, and thereby dispense with the need for a large squad of observers, would be far greater than those of the instrument usually first thought of; namely, a convenient substitute for the eye in ordinary photometry.

Preceding the work on the physical photometer proper, an

FIG. 2.



Flicker photometer arranged for obtaining luminosity curves of the spectrum.

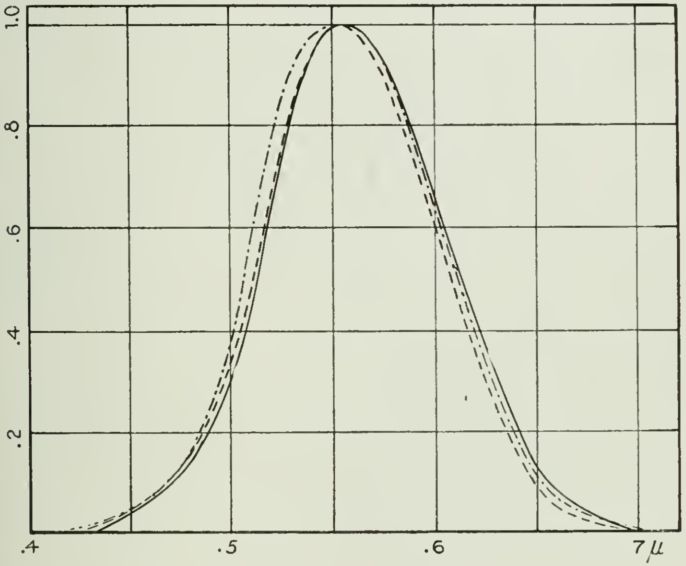
1, Observing slit; 2, prism table; 3, collimator slit; 4, divided drum; 5, wave-length drum; 6, white sector desk; 7, photometer bench; 8, standard lamp; 9, diffusing glass; 10, light source; 11, photometer bench; 12, diaphragm.

extensive investigation of colored light photometry was carried through.[1] From it was developed a special photometric method. By this photometric method determinations have been made of the luminosity curve of the spectrum, using a large number of observers. In addition a group of test colors has been evaluated, the whole constituting the establishment of a luminosity scale, similar in some respects to the temperature scale with its fixed points.

The photometric method adopted as the basis of this work involves the use of the flicker photometer at a certain illumination, with a definite size of the photometric field. In addition, and quite as important, it calls for a large group of observers.

In Fig. 2 is shown diagrammatically the flicker photometer as arranged for obtaining the luminosity curve of the spectrum. It consists essentially of a spectrometer to provide the various spectral radiations, and a disk half transparent to allow the colored light to reach the eye, and half diffusely reflecting the light from a fixed light source. When slowly rotated this disk performs the function of alternating the colored and standard light; it is, in other words, a flicker photometer. When the spectral light is made of a certain intensity no flicker is produced by the process of alternation, and the spectral and other light are equally bright upon the flicker photometer criterion. This criterion has been decided, on the basis of the research which preceded, to be the most satisfactory one.

FIG. 3.



Luminosity curves of the spectrum.
Dot and dash line . — . — curve as determined by Ives.
Dash line — — curve as determined by Nutting.
Full line —— curve demanded for agreement between visual photometry and physical photometry. (Transmission curve of absorbing solution used in thermopile artificial eye.)

One more measurement is necessary; namely, the amount of radiant power represented by the colored light. What is required ultimately is the relative brightness of spectral radiations of the same power value, or the luminosity curve of the equal energy spectrum, as it is called.

In Fig. 3 are shown two luminosity curves of the spectrum obtained in this way, each involving about twenty observers, and differing in the way in which the value of the radiant energy was obtained. They show the brightest part of the spectrum to lie in the yellow-green.

It should be possible, with the luminosity curve thus determined, to proceed at once to the physical photometer. The fact that these curves differ somewhat, that the sources of error are rather large, and that it is now known that a still larger number of observers is really necessary, suggested the desirability of establishing the values of other color differences, more easy to fix accurately, and which could be measured by a sufficient number of observers to meet our criterion for being "average."

We have, therefore, determined by the same photometric method, using a group of 61 observers, the transmissions of a number of inorganic salt solutions, representing a series of steps from nearly monochromatic light to the kind of color differences found in practical photometry of illuminants.[2]

When the actual problem of developing the physical photometer was reached we were, as a consequence of this preliminary work, in a very different position from any who had previously attempted the same task. We had what they had not—adequate means of determining whether the physical photometer performed satisfactorily when made; in other words, whether it read *right*.

4. *The development of practical physical photometers.*

Thus far two different means have been worked out for producing a light template to go in front of the radiation measuring instrument. The first of these, which may be characterized as a mechanical device, will be described under the title of "a precision artificial eye."[3] It is a delicate laboratory instrument fitted to be the final reference standard. The second instrument, also an artificial eye, is much simpler and less delicate, at a slight sacrifice in absolute precision. It is a practical instrument for the average physical laboratory.

The "precision artificial eye" consists essentially of a spectrometer which forms a spectrum of the light source. This spectrum is then passed through a mechanically cut template, whose aperture at each wave-length is exactly proportional to the luminous value of that wave-length of radiant power. By means of a condensing lens this spectrum is recombined into a small image of the prism face, and allowed to fall upon the receiver of a small vacuum thermopile of high sensibility. The thermoelectric current is measured by means of a Thomson galvanometer of the most sensitive type. This current is proportional to the *light* entering the slit of the instrument.

FIG. 4.

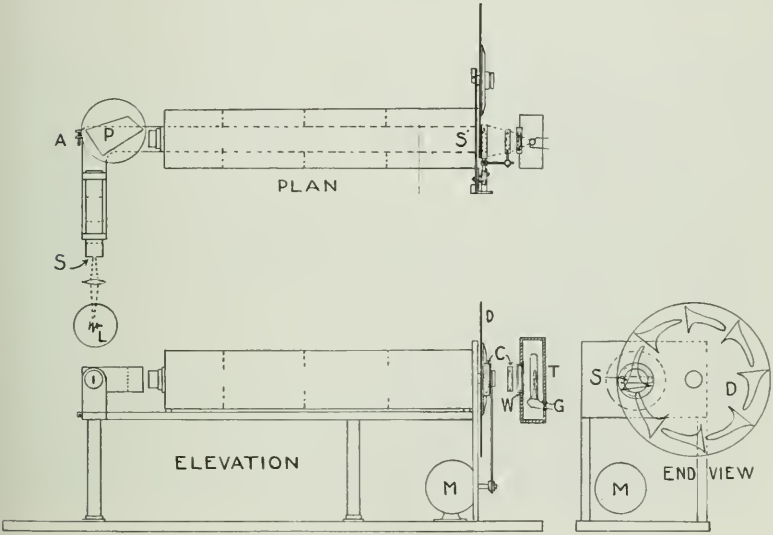


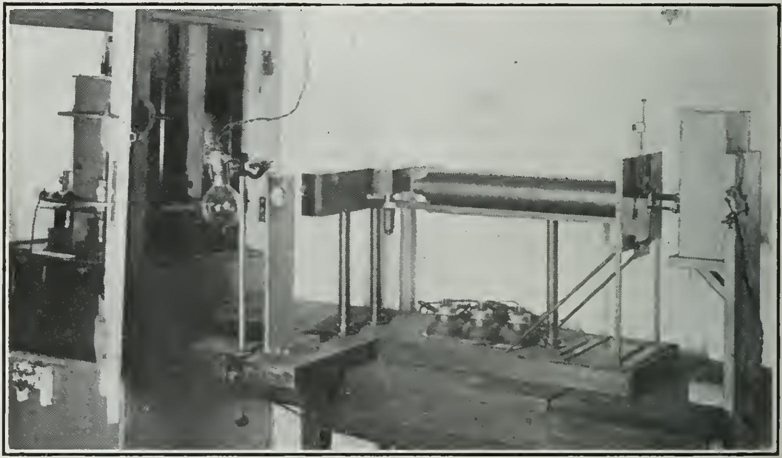
Diagram of precision artificial eye.

L. Light source.
S. Slit.
P. Prism.
A. Adjusting screw.
S'. Point of formation of spectrum.
C. Condensing lenses.
T. Thermopile.
D. Spectrum template.
G. Galvanometer leads.

The instrument as constructed is shown diagrammatically in Fig. 4 and by means of a photograph in Fig. 5. The light from a lamp (*L*) passes through a condensing lens, which focuses it upon the slit (*S*). A spectrum is formed at *S'*, in which plane lies the light template, which may be either a rotating disk, as shown in the diagram, or, in some cases, a fixed opening as shown in the photograph, in either case the opening being cut accurately to the shape of the spectrum luminosity curve as determined by the standard photometric procedure. The spectrum as recombined by the convex lens system falls upon the thermojunction (T), from which leads go to the galvanometer.

The term "precision" applies to this instrument for the reason that its design permits the exact copying of any luminosity curve, either experimentally found or embodied in some mathematical formula. It is thus qualified to be the final instrument of appeal in the standardizing laboratory. It has, however, its limitations, as all sensitive instruments have. The light measured must be of considerable intrinsic brightness, because the process of spectral resolution and recombination is very wasteful of light. The thermopile and galvanometer sensibility must be very high—about of the order of magnitude necessary to measure the radiation of the stars. The practical effect of these limitations is that the device is best used for measuring not light sources themselves, but auxiliaries used in light measurement, such as absorbing screens of various colors by means of which color differences may be eliminated in practical photometry. This function is all that is at present really necessary in a precision artificial eye, but it is to be expected that in time such greater sensibility can be attained that more varied needs can be directly taken care of.

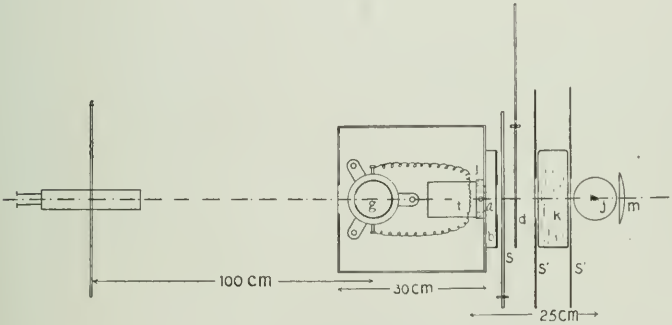
FIG. 5.



Precision artificial eye.

The second instrument to be described is also a thermopile artificial eye,[4] which, however, differs from the first in being much simpler and more generally practical. Its essential feature is the use of an absorbing solution in place of the mechanically cut spectrum template. This absorbing solution should have a transmission at each wave-length proportional to the luminous efficiency of that radiation. It will be readily grasped that the attainment of an exact copy of the spectrum luminosity curve by the transmission of one or a mixture of several absorbing media is a task of no small magnitude. In so far as this must merely be an approximation must this form of physical photometer fall short of being a precision device. Nevertheless, it has been found possible to copy the luminosity curve very closely indeed and so construct a physical photometer of this type, which is now in almost daily use.

FIG. 6.



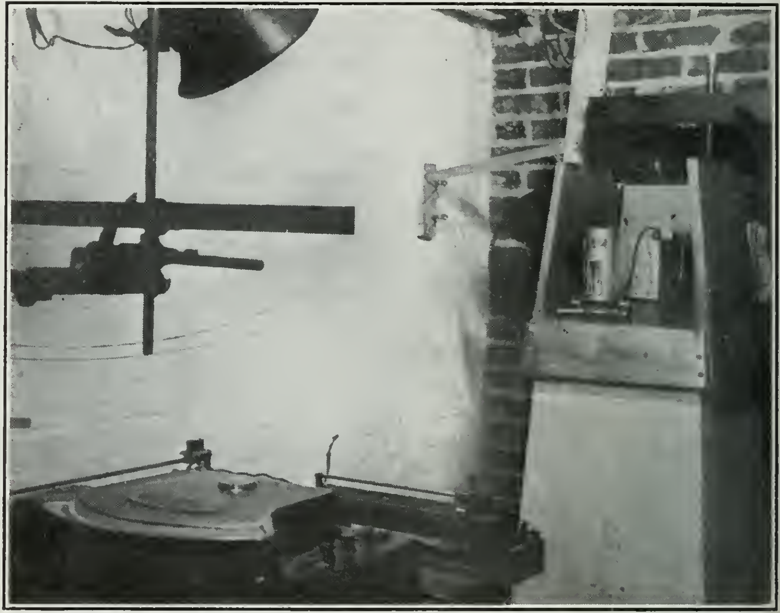
Physical photometer.

t. Thermopile.
g. Galvanometer.
l. Luminosity curve solution.
s. Shutter.
d. Sector disk.
s'. Screens.
k. Water tank.
j. Light source.
m. Concave mirror.

Fig. 6 shows this instrument diagrammatically. The radiation from the light source passes through the " luminosity curve " solution (*l*) to the surface thermopile (*t*), which is connected to a sensitive d'Arsonval galvanometer whose deflections are read by the telescope. A water tank (*k*) is used to prevent the luminosity curve solution from becoming heated, and to completely exclude such infra-red as the solution (*l*) transmits, and various screens and shutters are added, as shown, whose purpose is obvious. In its essentials, however, the instrument is extremely simple, as is its operation. A photograph of the apparatus is shown in Fig. 7.

The heart of the device is, of course, the luminosity curve solution. In the evolution of the instrument a screen was first developed closely copying one of the experimentally found luminosity curves. This was then tried out with the test colors which had been measured by our large group of observers. Of these test colors, which have been mentioned before, two may be taken as typical. These, which we shall speak of hereafter merely as " the test colors," are a yellow and a blue absorbing solution which, when placed over a standard lamp, should measure equal. We have developed these primarily as a criterion for the selection of groups of observers who should have the same average characteristics as our large group of 61.[2] The physical photometer must, of course, measure these test colors as the average eye does by the visual photometric method. On test the first luminosity curve solution did not do this exactly. A certain displacement of the luminosity curve was called for, indicating that the luminosity curve of our large group of observers was different from that obtained in the direct determinations of this curve—due either

FIG. 7.



Photograph of physical photometer.

to an actual difference of the two groups, or to errors in the direct determination caused by the experimental difficulties. The shift called for was made by varying the relative proportions of the constituents until the test colors (and other test colors) measured exactly as they were determined by the visual method.

The constitution of the final luminosity curve solution is as follows, for one centimetre thickness:

Cupric chloride	60 grammes
Cobalt ammonium sulphate	14 grammes
Potassium chromate	1.9 grammes
Nitric acid (1.05 gr.)	18 c.c.
Water to	1 litre

With this must be used a protective water tank of at least 2 cm. thickness.

The spectrum transmission is shown in Fig. 3.

The characteristics of this physical photometer may be summarized thus: It measures by the simple motion of a pointer over a scale the relative luminous intensities of lights of different color with a precision comparable with the best visual photometry, and the result is the same as would be given by the mean of a very large group of observers using the best visual method.

The only important limitation to the instrument as it stands is that the luminosity curve solution is only a close approximation. It has been tested out on all the ordinary color differences among illuminants for which it will be used, but should be used with caution for other color differences. In other words, it should be compared in that case with visually determined values or with the precision instrument above described. It is to be expected that a further study of absorbing media would result in a still closer approximation to that spectrum luminosity curve which shall be decided upon as standard.

The present practical limitation to the physical photometer is its comparatively low sensibility. It is distinctly a laboratory instrument. Its chief use lies in the calibration of colored light standards for use outside the laboratory by ordinary visual photometry, with the color differences thus artificially eliminated. It is not, perhaps, too much to hope that means will be found in course of time to increase the sensibility of radiometric devices to an extent which will make the physical photometer an instrument available even in street-light photometry. An attractive possibility is some form of amplifier similar to the amplifying devices used for wireless telegraphy receivers.

5. *The question of luminous efficiency.*

The previous section has described how the process of light measurement has been made similar to, and nearly as simple as, the ordinary measurement of voltage, current, or power. But the contributions of the spectrum template conception to light measurement are not exhausted with that step. A satisfactory means of measuring the efficiency of light production is also furnished. This will now be described, partly because of its intrinsic importance, partly because it serves as an excellent mode of approaching the question of a rational standard of light.

By the efficiency of a piece of mechanism is universally understood the ratio of output to input, of useful work to power applied. If all the applied power is returned by the machine as useful work the efficiency is 100 per cent. It is a prerequisite to the expression of efficiency on a percentage basis that both input and output be measured in the same units.

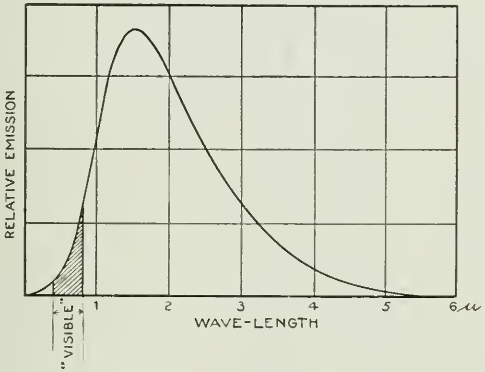
Lighting science has been behind other branches of engineering in this matter, because there has been no percentage basis of comparison. We have been able to say, by comparing the lumens per watt of one illuminant with the lumens per watt of another, what their relative efficiencies are, but whether they are intrinsically efficient transformers of power into light is not indicated.

Curiously enough, there are two measures of luminous efficiency to be found in the literature of lighting. Each has one good point and one bad. The common physical measure of so-called " luminous efficiency " is illustrated by Fig. 8. It consists in the ratio of the " visible " radiated energy to the total radiated energy. By " visible " is meant a certain portion between rather arbitrary limits in the red and violet portions of the spectrum. This ratio, which is with more propriety called the " visible fraction " of the radiation, gives only the crudest sort of idea of light-producing capacity, for it gives just the same weight to the deep red and violet parts of the spectrum, which are comparatively non-luminous, as to the most luminous part in the green. On this basis two illuminants many times different in illuminating power could rank as equally " efficient." The one good point about this method is that this "visible fraction" is expressed in percentage values.

The engineering measure of luminous efficiency is "lumens per watt," a true comparison of useful output (namely, illuminating power) with input. But, as already indicated, this is on a scale whose bottom is known (zero), but whose top is not. Consequently it is not on a par with the simple percentage figure in which we can express the efficiency of a transformer.

What is called for is a measure of efficiency which shall apply the percentage scale to the measurement of true lighting usefulness. Such a measure is supplied by utilizing the spectrum luminosity template.

FIG. 8.

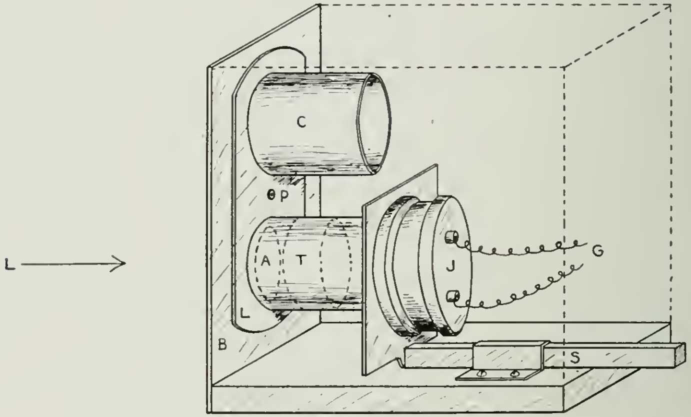


The "visible fraction," formerly called the "luminous efficiency" of the radiation of an illuminant.

Consider first the evaluation of the efficiency of the *radiated* power. We have already seen that the power which is transmitted through the visual luminosity curve screen of the physical photometer is directly proportional to light. If now we measure as well the radiation *without* interposing the luminosity curve screen, and compare the two quantities, we have a ratio of illuminating power to radiated energy. The relative values of this ratio from one illuminant to another are exactly as their relative lumens per watt. We have, in short, a measure of relative efficiency of light production.

But one step is needed to make this an absolute measure of efficiency. What value is given in such a measurement to the radiation of highest possible efficiency of light production? It obviously depends on the absolute transmission of the luminosity screen at the wave-length of maximum efficiency (0.56μ). If this transmission is *unity* the most efficient radiation will measure 100 per cent. by this procedure. Let us define such a luminosity curve screen of maximum transmission unity as an *ideal luminosity curve screen.* The measurement of the luminous efficiency of any radiation then becomes simply the measurement of the ratio of the radiation transmitted by the ideal luminosity curve screen to the total radiation. Efficiencies are expressed on a percentage scale whose unit is the most efficient possible radiation.

FIG. 9.



Instrument for measuring the luminous efficiency of any radiation.
L. Radiation entering instrument through aperture *A.*
J. Thermopile connected to galvanometer by leads *G.*
C. Unobstructed tube.
T. Tube containing luminosity curve solution.
L. Plate, pivoted at *P* so that either *T* or *C* may be placed before *J.*
The radiation from the light source is first measured entire, as it passes through the unobstructed tube *C.* It is then measured after passing through the luminosity curve solution *T.*

Recently Dr. E. Karrer [5] has made a series of measurements of radiant luminous efficiencies in accordance with this idea. The luminosity curve screen used was similar to that described in connection with the physical photometer. To reduce the results to those which an ideal screen would give it was only necessary to divide the measured value through the screen by the maximum transmission of the screen and to make some small corrections, due to the small variations of the actual screen's transmission curve from the shape of the ideal one.

Fig. 9 shows a complete arrangement for measuring the luminous efficiencies of the radiant power of illuminants upon this rational basis. In Table I are some representative values of ordinary illuminants. It is to be noted how excessively low are the efficiencies—only a few per cent.—of our best artificial light sources even when we consider only that portion of the applied power which has already been converted into radiation.

TABLE I.

Radiant Luminous Efficiencies of Light Sources.

1. Standard "4-watt" carbon lamp	0.0045
2. Vacuum tungsten lamp, 1.25 w. p. c.	0.0165
3. Welsbach mantle, 0.75 per cent. ceria	0.012
4. Open gas flame	0.0019
5. Nernst glower, 8-ampère	0.0108
6. Nitrogen-filled tungsten lamp, 0.65 w. p. c.	0.029

Attention has purposely been given so far only to the luminous efficiency of the radiation, but our interest is as great, or even greater, in the *total efficiency* of a light source; that is, the efficiency of utilization of the applied power. This is immediately arrived at by a knowledge of the efficiency of the transformation of the applied power into radiation. The ratio of the watts radiated to the watts applied may be called the *radiation efficiency,* and, both applied power and radiated power being measured in the same units (as they should be), this ratio is a straight percentage. We then have, quite simply, that the total efficiency of a light source is the product of its radiation efficiency by the luminous efficiency of its radiation. The full significance of this is shown by considering the case where all the applied power is transformed into radiant power with no loss, and this radiant power is in the form of yellow-green light (wave-length 0.56μ). The radiation efficiency is 100 per cent.; the luminous efficiency of the radiation is 100 per cent.; hence the total luminous efficiency is 100 per cent. In short, we have developed, through the use of the ideal luminosity curve screen idea, a measure of the efficiency of light production in which the unit is the most perfect possible transformation of the applied power into light. The measurement of luminous efficiency is thus made exactly parallel with the measurement of other efficiencies.

In order to get actual values of total luminous efficiencies it is only necessary to have a set of values of radiation efficiencies to multiply by the values of radiant luminous efficiency in Table I. As a matter of fact, no extensive measurements of radiation efficiencies are on record. Consequently the values of total luminous efficiency which have been obtained thus far have been arrived at along a slightly different road.

It has been pointed out that one reason for the chaotic state which has held in regard to luminous efficiencies is that power input and useful work (light) are commonly measured in different units. Most of our data on the efficiencies of illuminants are in the form of lumens per watt. If in place of the lumen we could use the watt to measure light we would have a ratio of watts to watts; that is, a fraction or percentage. In the next section it will be shown that this can be done. The value of the lumen in watts of luminous flux will be found, and by substituting this for the lumens in the lumens per watt values figures will be obtained for total luminous efficiencies.

6. *The mechanical equivalent of light.*

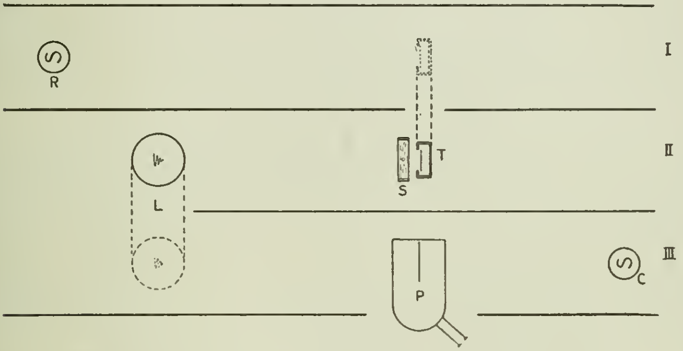
What is here to be defined as "the mechanical equivalent of light" can best be understood by asking: "What does the physical photometer equipped with an ideal luminosity screen actually measure?"

Consider a light source, supplied with a certain number of watts of power, of which a certain proportion are radiated and are received either by the eye or by the physical photometer with the ideal screen. That which reaches the retina and has been evaluated as light, as though it passed through a hypothetical luminosity curve screen, we measure in lumens. That which reaches the radiometer and which has been evaluated according to its light value by a concrete luminosity curve screen we have as yet not considered describing in any definite unit. We only know that it is always exactly proportional to the lumens. Now ordinarily radiant power incident on a radiometer would be measured in the standard power unit, the watt. Let us call the watt of radiant power which has been evaluated as light by an ideal luminosity curve screen a *watt of luminous flux*. We then measure the same radiation in lumens by using a visual photometer, and in watts by using the physical photometer. These two being always proportional, it follows that the lumen is some multiple of the watt of luminous flux.

The "mechanical equivalent of light" is here defined as the number of watts of luminous flux in the lumen.

A recent investigation has been devoted to the determination of the value of this constant. Two different methods were used, of which only one need be mentioned here. The general principle is to measure the same radiation both in lumens and in watts of luminous flux. The apparatus (very much the same as the simple physical photometer and the luminous efficiency meter) is shown diagrammatically in Fig. 10. The radiation from a light source falls upon one-half of a photometer field, and is evaluated, by approved photometric methods, in lumens per unit area. The light source is then moved so that its radiation falls on a radiometer, over which is an ideal luminosity curve screen. The intensity of the radiation is registered, after which the radiometer is exposed to the radiation of a standard of radiation. This gives the equivalent in watts of the previous measurement. We then have the value of the same radiation in lumens and in watts of luminous flux, from which their ratio is at once derivable.

FIG. 10.



Apparatus for determining the mechanical equivalent of light.

R. Radiation standard.
T. Thermopile.
S. Luminosity curve solution.
L. Light source.
C. Luminous standard.
P. Photometer head.

I. Position of thermopile for determining sensibility of thermopile-galvanometer system (watts per square metre per centimetre deflection).

II. Position of thermopile and light source for measuring luminous flux, in watts per square metre.

III. Position of light source for measuring luminous flux, in lumens per square metre.

The experimental determination fixes the lumen as having a value of 0.00159 watt of luminous flux.[6]

The first use to be made of this figure is the calculation of total efficiencies of light production. We have but to take the efficiency of an illuminant in lumens per watt and transform the lumens to watts of luminous flux, by multiplication by 0.00159, to obtain the ratio:

$$\frac{\text{watts of luminous flux}}{\text{watts of applied power}}$$

From our method of defining the watt of luminous flux it follows that in the case of the most efficient possible transformation of applied power into light one applied watt yields one watt of luminous flux. The ratio just given, therefore, expresses total luminous efficiencies as a percentage of the highest possible efficiency. It is the same as the ratio obtained from the product of radiation efficiency by the luminous efficiency of the radiation, to which idea we arrived in the last section.

In Table II are shown the total luminous efficiencies of some representative illuminants. These efficiencies are even lower, as they must be, than the efficiencies of the radiated power as given in Table I. From these two tables it is possible to obtain the radiation efficiencies, the ratio of the total to the radiant luminous efficiencies. In the case of the vacuum electric lamps this is of the order of magnitude of 90 per cent. or over. With the gas mantle light it is about 16 per cent., showing the large part of the applied power lost by convection and conduction of heat.

TABLE II.[7]

Total Luminous Efficiencies of Light Sources.

1. Standard "4-watt" carbon lamp	0.0042
2. Vacuum tungsten lamp, 1.25 w. p. c.	0.013
3. Welsbach mantle, 0.75 per cent. ceria	0.0019
4. Open gas flame	0.00036
5. Nernst glower	0.0077
6. Nitrogen-filled tungsten lamp, 0.65 w. p. c.	0.026
7. Yellow flame arc lamp	0.072
8. Quartz mercury arc lamp	0.068
9. Carbon arc, D. C.	0.019
10. Acetylene flame	0.0011

7. *The fundamental standard of light.*

The common discussion of standards of light, to be found in text-books on photometry, deals with the mechanical characteristics of certain illuminants, which for one reason or another have been selected as custodians for the unit of luminous flux. We have, for instance, the sperm candle, the Hefner lamp, the pentane lamp, etc. By adhering closely to certain specifications as to dimensions and to certain requirements of chemical composition of the fuel, these standards are reproducible from specifications. That is, however, their only claim to be called standards. Actually the luminous flux unit of this country is maintained by sets of incandescent electric lamps, not reproducible from specifications, but of proved permanence of characteristics when properly handled. The problem of *maintaining* a unit is, in fact, in excellent shape, but the unit which is maintained is of dimensions fixed by history rather than science.

We have seen that luminous flux can be measured in watts, and that by so doing the efficiency relationships are taken care of in a simple and orderly way. The question now arises: "Why is not luminous flux properly measured in watts?" The answer is that it is; the only reason other units are in use is that they became established long before the relationship between light and power was understood.

The proposal here made is that the present units of luminous flux be superseded. In their place *the watt should be adopted as the unit of luminous flux.*[8]

By so doing lighting science can be placed on the same absolute basis as other physical sciences, removing it from its present anomalous position.

The transition from the present unit to the new one is (apart from commercial considerations) quite simple. The present unit maintaining standards need merely have new values assigned to them differing from the old in the ratio of 0.00159 (the mechanical equivalent of light). The greatest difference will be in the method of checking these standards with the fundamental quantity. Instead of founding our work on certain arbitrary conditions of fuel combustion, reference will be made to a standard of radiation, which is one of the regular physical standards, maintained for a variety of uses. *Any* light source which gives one watt of radiation through an ideal luminosity curve screen is giving one watt of luminous flux or one light watt. It is, therefore, necessary to maintain the standard of radiation, and to have the ideal luminosity curve screen (or a screen very closely ideal from whose results the ideal can be readily calculated). The watt standard of luminous flux is then based on a physical specification; and a physiological one, which is the simplest analysis of which it is capable.

It is to be noted that there are two alternative, but exactly equivalent statements of this logical unit; namely, one watt of radiation of maximum possible luminous efficiency, or $\frac{1}{L}$ watts of radiation of luminous efficiency L.

8. *Discussion.*

A word may be said on the simplifications introduced by the adoption of the light watt. At present an anomalous condition exists in the manner of describing the characteristics of illuminants. Formerly light sources were commonly described as of so many candle-power, which is different in every direction. Approved practice now dictates that a lamp should be described by the amount of light flux it gives; that is, by the number of lumens.[9] This practice has not been at all widely followed, largely because the lumen appeals to most as an additional, not-well-understood and confusing unit. The practice with regard to electric lamps has been to hold to the well-known unit, the watt; but the only watt which has been measured is that of the power supplied. We thus find incandescent lamps described, not by what they give but by what they use. A 100-watt lamp is one consuming 100 watts. To find what light it gives we must have another figure: its lumens per watt, or specific consumption.

In other branches of engineering it is common to specify a machine by what it gives. A ten-kilowatt engine gives ten kilowatts, and its efficiency is so much. By the use of the light watt illuminants may be similarly specified without introducing a new term. A two-watt lamp will be one that furnishes two light watts. Its efficiency shows how many watts of applied power are necessary to yield the light.

The fact that the most efficient illuminants we now have will thus be denominated by a low figure in light watts, but will necessitate the expenditure of forty or fifty times that amount of applied power, may be unpopular with illuminant manufacturers, but will render a decided service if it spurs them still more to improvements in the most wasteful of all technical processes of power utilization—light production.

It is perhaps not out of place to say a word on the subject of the probability of this new unit being generally adopted. It is, of course, always extremely difficult to displace anything well established, no matter what its shortcomings. An exactly parallel case is furnished by the metric system of weights and measures. The most that has been accomplished thus far in this country, aside from scientific fields, is to legalize its use. The relations between the old arbitrary system and the metric have been definitely established and legally recorded. The transition from the old to the new system can be made as fast as the public wants it made. In a similar way the light watt might be recognized as a legal unit, connected by a definite constant of proportionality with the present practical units. It might, with the rest of the metric system, be used in scientific work with the hope of its ultimate practical adoption. The fact, however, already noted, that the adoption of the light watt will actually appear as a simplification, because it does away with some names now necessary and peculiar to photometry, may promise an earlier adoption than has been vouchsafed to the centimetre and the gramme.

9. *Definitions.*

In this rapid review of the topics included under physical photometry it has been impossible to avoid the occasional loose use of certain terms, or the assumption of considerable previous knowledge on the part of the reader. In order that the various quantities and relationships may be available in exact and rigid form, the following list of definitions is given. These definitions are all in harmony with the physical methods here described, and include as well quantities of use in the transition from the present arbitrary units to the ones proposed.

Power consumed by a light source $=P$; expressed in watts, a portion of which is dissipated by radiation, the remainder by conduction and convection.

Power radiated by a source $=R=\int_0^\infty R\lambda\, d\lambda=$ power emitted by a light source in the form of radiation between wave-lengths 0 and ∞, expressed in watts.

Radiation efficiency $= \frac{R}{P} =$ ratio of the power dissipated as radiation to the total amount of power consumed by the source. (A pure numeric.)

Luminous flux $= F =$ radiant power evaluated according to its capacity to produce the sensation of light.

Light evaluating factor or stimulus coefficient of any radiation is the ratio of the luminous flux, in its appropriate units, to the radiant power producing it, in its appropriate units.

The luminous efficiency of any radiation $= L_R =$ the relative capacity of the radiation to produce the sensation of light, compared with the capacity of the same quantity of radiation of the maximum possible light-producing capacity. (A pure numeric.)

> The luminous efficiency of any radiation is the mean value of the luminous efficiencies of its component monochromatic spectral radiations. These latter are specified by the luminosity curve of the normal equal energy spectrum, of maximum value unity. The spectral luminosity curve is obtained by the standard photometric method for colored light photometry.
>
> To a close approximation the spectral luminosity curve is represented by the expression:

$$L_\lambda = A\left(\frac{R_1}{\lambda}e^{1} - \frac{R_1}{\lambda}\right)^{\alpha} + B\left(\frac{R_1}{\lambda}e^{1} - \frac{R_2}{\lambda}\right)^{\beta} + C\left(\frac{R_3}{\lambda}e^{1} - \frac{R_3}{\lambda}\right)^{\gamma}$$

where

$A = 0.999$ $R_1 = 0.556$ $\alpha = 200$
$B = 0.04$ $R_2 = 0.465$ $\beta = 400$
$C = 0.095$ $R_3 = 0.610$ $\gamma = 1000$

Total luminous efficiency of a light source $= L_T =$ the relative capacity of the power applied to a light source to produce the sensation of light, compared with the capacity of the same quantity of power in the form of radiation of maximum possible luminous efficiency. (A pure numeric.)

Units.—Luminous flux is connected to radiant power by a numerical evaluating factor. The unit of power is the watt. The present arbitrary practical unit of luminous flux is the lumen. The light evaluating factor or stimulus coefficient is consequently expressed in lumens per watt. If for this evaluating factor is taken the *luminous efficiency* as above defined, the unit of luminous flux is the same as that of radiant power or applied power; namely, the *watt.*

In the symbols proposed:

$$P \times \frac{R}{P} \times L_R = P \times L_T = F.$$

In order to go over to the watt as the unit of luminous flux it is necessary to know the:

Mechanical equivalent of light—the value of the lumen in watts of luminous flux.

(The lumen is approximately 0.00159 watt of luminous flux or light watts.)

(The terms "specific consumption," "specific output," etc., involving relationships between watts and lumens, are superseded by the method of defining luminous efficiency, and by the adoption of the watt as the unit of luminous flux.)

The quantities derived from luminous flux (*e.g.,* illumination, luminous intensity, and brightness) are to be defined as at present, with the necessary substitution of the watt of luminous flux for the lumen wherever occurring. It is suggested that the new unit of luminous intensity on the watt basis might be called the "pyr."

10. Summary of work accomplished and statement of that still necessary.

This paper summarizes a series of investigations extending over several years, having for their object the simplification and rationalization of light measurement.

A physical photometer or artificial eye has been developed to practical form, whereby the results of an average eye may be obtained, with almost the simplicity of the measurement of voltage or current. The measurement of the efficiency of light production has been put on a rational basis. A new unit of light flux is proposed, through the use of which photometry is made a part of the centimetre-gramme-second system. The value of this unit in terms of the present one has been determined.

No research is final, and it is but proper to point out in what way this one may be carried to still greater usefulness.

The primary object of the work was to establish methods. In this it has been eminently successful. At the same time every effort was made to obtain numerical results of value. The value of these numerical results is somewhat less than that of the methods, and for obvious reasons. As the work progressed from stage to stage additional light was thrown on the parts previously completed. It was found, for instance, from work done near the end, that a much larger number of observers was necessary for the determination of the spectral luminosity curve than had been thought necessary at the time that part of the research was done. It was found, too, that a curve different from the experimentally-found one was clearly called for. The luminosity curve finally decided on is actually determined only by the transmission curve of a certain inorganic salt solution. These shortcomings do not affect the validity of the methods, but they prevent the results from claiming the highest accuracy. A repetition of the numerical determinations by the same methods, but profiting by the experience obtained in the present study, should establish the constants of physical photometry with a high degree of accuracy.

Before such a repetition is undertaken, however, it is of extreme importance that the foundation of it all, namely, the spectrum luminosity curve of the average eye, be determined with the very highest accuracy possible, using an adequate number of observers. This is a task which would be most appropriately undertaken by such an organization as the Bureau of Standards.

A question frequently raised in this connection is whether it would not be feasible simply to adopt as standard some luminosity curve of the spectrum, either an experimentally determined one or a simple mathematical curve, and thereby dispense with the need of further experiment. The answer to this is that if *all* photometry were done physically any curve could be agreed upon. Since, however, a certain amount must be done visually, and the final criterion of usefulness is visual, the necessity for *agreement* between visual and physical must be met. As to how close this agreement need be, or whether a certain compromise may not be permissible when the agreement has reached a certain stage, there is room for debate. In the present work the luminosity curve used in the physical photometer has been altered from the directly determined ones in order to make the visual work the final criterion. At an appropriate time this process could, if desired, be reversed. The precision artificial eye could be equipped with a legally adopted curve with which the values of the test colors could be established. Observers for visual work could then be selected who would measure the test colors in this new ratio instead of the visually established one. The complete scale would then be established by the determination of the mechanical equivalent of light on the basis of this curve, a simple matter by the method described. Or the transmission of some solution might be adopted for the standard luminosity curve, and a similar process gone through. It would, for instance, be perfectly feasible to take the test-color ratio, as determined by a solution matching the luminosity curve determined by the author, which is only two or three per cent. off the present mean visual ratio, and base the selection of observers for visual work on this ratio. Obviously this could not be done if the disagreement between the two methods of approach was greater than the range of variation to be expected in any ordinary group of observers. Hence the need for a pretty close agreement between the various modes of approach before such a partly arbitrary solution to the problem may be seriously considered. The agreement between the visually established scale and the physical one here used is quite good enough to form the basis of such a resort to legislation (for instance, by the technical societies and government bureaus). The further work indicated would, however, in the writer's opinion, be ultimately called for by the increasing demands for accuracy in technical measurement.

Physical Laboratory,
United Gas Improvement Company,
Philadelphia, May 20, 1915.

REFERENCES.

[1] Ives, "Studies in the Photometry of Lights of Different Color," *Phil. Mag.*, July, Sept., Nov., Dec., 1912.

[2] Ives and Kingsbury, "Experiments on Colored Absorbing Solutions for Use in Heterochromatic Photometry," *Trans. Ill. Eng. Soc.* No. 8, 1914, p. 795. "Additional Experiments on Colored Absorbing Solutions for Use in Heterochromatic Photometry," *Trans. Ill. Eng. Soc.*, 1915, No. 5, p. 253. "Flicker Photometer Measurements on a Green Solution," *Phys. Rev.*, March, 1915, p. 230. "On the Selection of a Group of Observers for Heterochromatic Measurements," *Trans. Ill. Eng. Soc.*, 1915, No. 3, p. 203.

[3] Ives, "Precision Artificial Eye," *Phys. Rev.*, 1915.

[4] Ives and Kingsbury, "Physical Photometry with a Thermopile Artificial Eye," *Phys. Rev.*, 1915.

[5] Karrer, "A Method of Measuring Radiant Luminous Efficiencies," *Phys. Rev.*, March, 1915, p. 189.

[6] Ives, Coblentz and Kingsbury, "The Mechanical Equivalent of Light," *Phys. Rev.*, April, 1915, p. 269.

The value now given differs by two per cent. from the one given in the paper just quoted. This changed value results from the application to the original data of two corrections; one, that due to the adoption of the luminosity curve called for by the physical photometry investigation, in place of the Nutting curve; two, that due to the elimination of the effects of an infra-red transmission band in the luminosity curve solution originally used. On the assurance of Dr. Coblentz, who collaborated as radiation expert, that no such transmission band could be present, much time and study were given to the harmonizing of the two sets of data comprising the experimental part of that investigation, which was finally arrived at by the adoption of the Nutting luminosity curve. Extended work with the physical photometer later showed clearly that this curve was unsatisfactory, and at the same time proved the necessity for the additional protection of a considerable depth of water, indicating an infra-red transmission band to be present after all. Very fortunately, a simple measurement of the luminous efficiency of a "4-watt" lamp with the old unprotected and the new correct solution gives at once the correction to be applied. As a result of this measurement we find the net result to be the justification of the new luminosity curve and the two per cent. correction above noted. The agreement of the various mechanical equivalent measurements is even better than as originally published; the final value may lay claim to high accuracy.

[7] Ives, "The Total Luminous Efficiencies of Present Day Illuminants," *Phys. Rev.*, May, 1915, p. 390.

[8] Ives, "The Primary Standard of Light," *Astrophysical Jour.*, Nov., 1912, p. 322.

[9] The description of a light source by its total light flux (as recommended by the Illuminating Engineering Society) is not to be interpreted as a criticism of the common laboratory practice of confining measurements of intensity to a single direction. The factory examination of incandescent electric lamps by the measurement of their horizontal candle-power, or the measurement of the quality of illuminating gas by the luminous intensity of a flame in a certain direction, are illustrations of a general laboratory procedure adopted to reduce to a minimum the actual labor of measurement. This procedure consists in investigating the property on which information is desired by determining the value of some easily-measured factor to which the property in question bears a constant and known ratio.

RECENT PROGRESS IN MILITARY AËRONAUTICS.*

BY

LIEUT.-COL. SAMUEL REBER,
In charge of the Aviation Section, Signal Corps, U. S. A.
Member of the Institute.

The first decade of the twentieth century has added to the mechanical engines of war two types of apparatus, one heavier than and the other lighter than air. While the rigors of warfare will be apparently increased by their use, they will prove potent factors in the disappearance of war from the forum of the world as the ultimate means of arbitrament for international controversies. The application of mechanical flight to warfare is but an added proof of the maxim of the German strategist who said, " War is the only science that lays under tribute all other sciences." Any progress in mechanical arts that tends to shorten the duration of a war, even by increasing the destructive potentiality of its implements, is a real gain to humanity, and the discoverer of a process or the inventor of an engine which increases its horrors and destruction is a real benefactor to mankind, since the increased loss of life and property will certainly cause civilized nations to hesitate and seek other less drastic methods for the settlement of international differences before final appeal is made to the arbitrament of arms. The art of mechanical flight has extended the domain of warfare into three dimensional spaces, has created new means of observation, communication and attack, whose potentialities are now but partially realized by the great military powers, whose existence has brought into being a new arm of the service, and whose utilization has produced great changes in the military and naval policies of the great powers.

As sea power has been one of the dominating factors controlling the policies of great powers in the past, air power will be so in the future. The moral effect of the presence or absence of an efficient air force will be a deciding factor in hostile operations, and the commander who is without an efficient air fleet will be at a great disadvantage from the outset of operations, and will have the celerity and certainty of his movements greatly hampered by the feeling that his plans and disposition of his forces are known to his opponent through aërial reconnaissance. To achieve success without an aërial force, he must greatly outnumber his opponent. Information of the location and movements of the enemy are absolutely essential to any commander. Such information is usually obtained by the active use of cavalry in contact with the enemy or by secret service within his lines. An efficient air force will not only supplement but anticipate the reconnaissance work of the cavalry, and can penetrate miles beyond the line of contact, provided it is not opposed by similar and better aircraft of the enemy.

---

* Presented at a joint meeting of the Mechanical and Engineering Section and the Aëro Club of Pennsylvania held March 26, 1914.

The two best examples as to what might have happened had an army been supplied with a fourth arm were in the recent Russian-Japanese war. Had the Russian commander had an aërial reconnaissance force at his disposal, it is more than probable that the results of the two decisive battles of Liao Yan and Mukden would have been entirely different. Had Kuropatkin checked the Japanese advance on the Tai-tse-ho in September, 1904, the outcome of the war would have been much more favorable to Russia. On Aug. 25, 1904, the Japanese attacked the Russian position in front of Liao Yan, and on the 27th the Russians, after an obstinate defence, retired to a second position, which was attacked without results until the 31st, when Oyama decided to send the first army under Kuroki to turn the left wing of the Russian position. On the 31st of August and 1st of September, Kuroki's army moved to the northeast and separated itself completely from the main position by a distance of ten miles. This movement was absolutely unknown to the Russian commander and, by its attack on the 2d of September, so relieved the situation along the main front that the Japanese advance, which had been completely arrested by the Russians, was renewed and Kuropatkin compelled to retire along the railroad to prevent his army being cut off from its line of communication. Kuropatkin's information had led him to believe that he was outnumbered at the beginning of the engagement by the Japanese, while, in fact, he had a decided superiority in men and guns. It must be evident that a few hours of aërial reconnaissance would have disclosed the real state of affairs and indicated the isolated position of Kuroki on September 1, and given Kuropatkin a splendid opportunity to capture or defeat with ease the entire first army. Again, in front of Mukden, Kuropatkin was unaware of the arrival of the third army, and even of the existence of the fifth army, nor did he have any information as to the extensive flanking movement of the third army from the 21st of February to the 1st of March, which movement ultimately compelled his withdrawal from his fortified lines. One single speed scout could have started from Kuropatkin's headquarters, circled the country over which the flanking movement was made, and returned and reported the movement within an hour and a half.

The functions of aircraft in war are fourfold: reconnaissance, both strategical and tactical; the prevention of similar reconnaissance on the part of the enemy; for communicating purposes, and for destructive action against the enemy.

The strategical reconnaissance by aircraft will cover all operations for the acquirement of information as to the location and movements of the enemy, and also of the terrain. When the reconnaissance becomes tactical in nature, as for example during an engagement, it will ascertain the location and disposition of the opposing troops, especially the reserves, and artillery positions, and inform the artillery commander of the effect of the fire of his guns. Whether reconnaissance will be made by dirigibles or aëroplanes will depend upon the available aëronautical material at the disposition of the commander general, the weather conditions, and the special object of the particular reconnaissance. For long-distance work, and especially for over-sea operations, the dirigible possesses certain desirable features, especially as part of the work is to be done at night. For the prevention of reconnaissance on the part of the enemy, there will be required types of fighting machines which can carry light automatic guns and possess a greater climbing ability than those of the opposing force.

For communication purposes the aëroplane is especially suitable. The conditions of modern warfare—the large extent of territory over which forces operate, and the length of the line of contact in a modern battle—render it extremely essential for the commanding general to have the swiftest means of communication, which is best furnished by aëroplanes.

The use of the aëroplane and dirigible for destructive operations offers a large field in the attack by explosives from overhead of permanent works, depots of supplies, dockyards, railroads, cities, and troops in position, but in the latter case the effect will be more moral than physical. A squadron of dirigibles or aëroplanes can compel a blockading fleet to remain a safe distance away from the shore, keep it constantly in motion, and cause greater coal consumption—a dominating factor in naval operations.

The possibilities of destructive aërial attack are well given in the following extract from a recent paper on aërial warfare by an officer of the French Army, Lieutenant Sensever:

" We shall see later on the possible utilization of the German aërial fleet for the destruction of works of art, arsenals, stations, or the direct struggle against enemies terrestrial or aërial. For the destruction of a city no problem of target practice arises; all shots count; the target is vast; no projectile is lost; no problem of defence is necessary for the aërostat, because in the night time it is invisible; no cannon can reach it; no aëroplane can pursue it; it is heard, but cannot be seen. Let us imagine on the evening of the declaration of war the ten Zeppelins, now in service, set forth with lights extinguished at an elevation of 1000 metres towards Paris. The compass, the luminous signals of the stations and railroads, the lights of the cities are guides which indicate the direction to an aërostat more clearly, in fact, by night than by day. In the silence of the country, in the nocturnal quietude after the sounds of the city, the distant roar of the motors will vanish, leaving behind it incertitude. What is there to do? The Zeppelins steer towards Paris. In four hours, if there be no wind, they will cover the distance which separates the Rhine from the French capital. Now they are above Paris, whose innumerable lights mark out the quarters, the squares, the avenues; then it is very simple. When each one arrives at its appointed spot, it accomplishes its task of destruction and death: to one, the stations where our soldiers will embark to-morrow; to another, the Ministry of War, the Elysée; to others, the forts or barracks at Versailles or Vincennes; to others, the Opera, the Louvre, Notre Dame, the Arc de Triomphe—all our glories and our forces! In a few minutes each Zeppelin has discharged its four or six bombs of 600 pounds each, in all about 50, or about 30,000 pounds of trinitrotoluol, which will level the beautiful quarters, which will kill millions of sleeping people, which will destroy gas mains, sowing conflagration and confusion in the terrorized city. During these few moments the Germans, from their nacelles, will contemplate their work—this spectacle that Nero never dreamed of. Then they will take their journey towards the east. At daybreak they are resting in their hangars along the Rhine, ready to start out again to-morrow."

The above is not an idle speculation, but could happen if the French are unprepared to meet the invasion of their frontiers through the air. England has this same menace threatening her across the North Sea.

Since the beginning of the twentieth century aëronautics have been used in three wars: the Russia-Japanese, the Bulgarian war, and the Turko-Italian, and in minor expeditions of the French and Spaniards in Africa. The dirigible had not been sufficiently developed, and the aëroplane was not in existence in the Russia-Japanese war, in which the Russians used captive balloons to advantage for observation purposes and for the direction of their artillery fire. The Japanese, though in possession of a balloon train, made practically no use of it during the war, though at Port Arthur there was an excellent opportunity for its use in locating the Russian fleet. Had the Japanese used a captive balloon the fleet could have been easily located and the siege expedited without the terrific loss imposed upon them by the capture of 203 Metre Hill, from which they obtained a view of the harbor and the ships. In the Turko-Italian war in Africa the Italians used both dirigibles and aëroplanes. These dirigibles, P–2 and P–3, only 4100 metres in size, made in all 91 flights, and P–3, engaged in the battle of Zanzur, discovered and routed a force of Turko-Arabic cavalry by dropping bombs. These dirigibles, assisted by aëroplanes piloted by Italian officers, were of the greatest value for reconnaissance purposes, and, though frequently exposed to hostile fire, escaped without material damage.

In the Balkan war it may be said that practically no effective use was made of aëroplanes by any of the belligerents, as they were entirely unprepared for this class of service. In the first war the Turks had two in front of Kirk-Kilissé which were broken down and did not fly. They had some others in the rear which were not used until after the Bulgars reached Chataldja. The Bulgars had no trained aviators, and were compelled to hire foreigners, who rendered them practically no service. The advantage to the Bulgars of a single aëroplane is illustrated by that period of loss of contact, October 24 to 27, 1912, when the Bulgarian cavalry broke down and they had no knowledge of the Turkish position.

At Adrianople the Turks had no aëroplanes. The Bulgars used a number which were mostly manned by foreigners. General Ivanoff summed up their use as follows:

"The best that can be said for the aëroplane is that the flights showed what great service they are capable of if well manned."

The Servians, while having four aëroplanes, did not put them in service. At Chataldja a number of flights were made for the Turks by foreign aviators, and the Greeks made several reconnaissance flights in their operations.

The lesson from the Bulgarian war is that material cannot be obtained and military aviators trained after the opening of hostilities, and that foreign or civilian aviators cannot be depended upon for efficient service. Experience has shown that for military aviation the pilots as well as the observers must be trained soldiers.

The first really successful ascent of a dirigible was made in September of 1884 by the "La France," built by Captains Reynard and Krebs. This balloon was only 51 metres in length, with a cubic capacity of 1864 metres, and driven by a 9-horsepower electric motor, giving it a speed of 14½ miles per hour. It was not until the beginning of the twentieth century that the French began the development of the present non-rigid type of balloon and added this to their military forces. The Germans, whose attention was drawn to the remarkable progress made by the French since the beginning of the century, began the development, under Count Zeppelin, of the rigid type of balloon. Experience has developed three separate types: the rigid, the semi-rigid, and the non-rigid, each possessing certain advantages and disadvantages for military purposes.

The rigid type is composed of a rigid frame of aluminum or wood in whose interior are a number of gas bags. The frame is covered by a light, permeable material, and the nacelles, carrying the motors, equipage, and crew, are attached to the frame. The Zeppelins have a frame of aluminum, and the Schutte-Lanz and Speiss types of wood. The envelope of the semi-rigid is completely flexible, and its form is maintained by the pressure of the inclosed gas, while the weight of the nacelle and the equipment is distributed along the envelope by means of a keel or longitudinal girder, as in the Gross, Lebaudy, and the Italian military dirigibles and those of the Forlanini type.

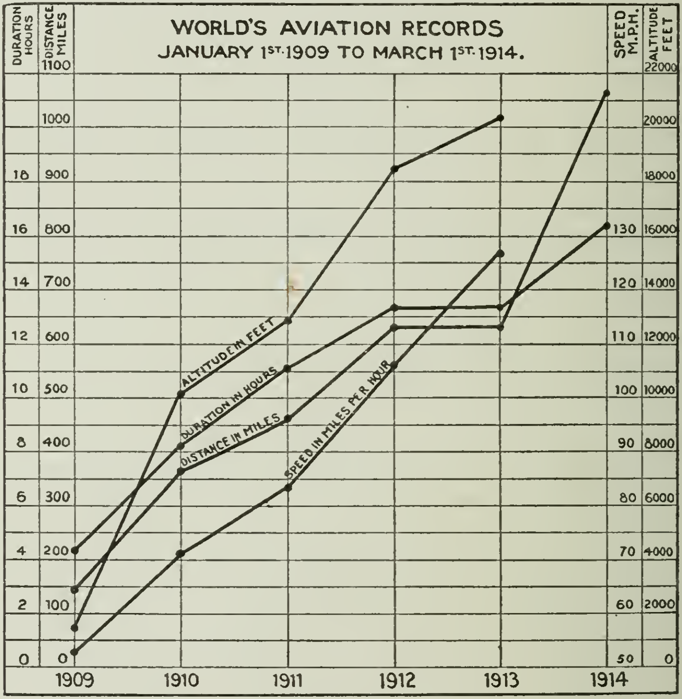
In the non-rigid the nacelle is directly suspended from the envelope, as in the Astra Torres, Parseval, Clement-Bayard, Zodiac, and the Siemanns-Schukert.

The rigid type possesses the advantage of greater speed, more inherent stability, and, on account of the construction, the possibility of carrying armament not only in the nacelle but on the upper surface; is less liable to damage from hostile fire, owing to the fact that the gas is not contained in one but several separate bags. The rupture of one does not cause the loss of the entire volume of gas. The rigid carries a larger crew and can remain longer in the air than the other types. The rigid type possesses the disadvantage of high cost, is more difficult to handle in starting and landing, requires a larger number of trained men in handling it in these operations, must be housed when not in motion, is more liable to damage or destruction in unfavorable weather, and more liable to accident, usually total destruction, in making bad landing, as evidenced by the accidents that have happened to the Zeppelins.

The semi-rigid offers a greater resistance, has less speed than the rigid but greater weight economy for equal volume, and is more easily handled and much less liable to damage in landing. It, as well as the non-rigid, can be anchored in the air when not in use, and is transportable, although the keel renders it less so than the non-rigid. The non-rigid has a slower speed in the air than the semi-rigid, is the easiest to handle, has the greatest economy of weight, and possesses the least liability to damage in landing, and is easily repaired and transported. The tendency is towards two types: first, the large, rigid, armed cruiser type, with a radius of action of 500 miles and an endurance in the air of thirty or forty hours. This type is assigned to permanent stations along the frontiers, with a zone of observation and defence. The second is a small, non-rigid type for over-sea operations. The Germans have developed this type of balloon more rapidly than the French and English, as it seems to be part of the German policy to offset England's supremacy on the seas by a German supremacy of the air. There are under construction in Germany dirigibles of this type up to 30,000 cubic metres capacity, with a lifting power of fifteen tons.

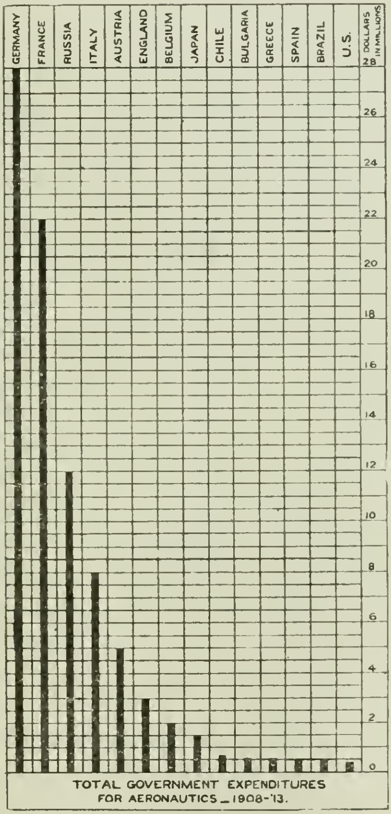
Since what may be called the real beginning of aviation in the year 1909 (Fig. 1), the records indicate a tremendous development in speed, distance, duration, and altitude. The relative importance that the various great powers have attributed to aëronautics in war may be inferred from the following (Fig. 2), which shows the amounts of money expended by them during the past five years ended in August last.

FIG. 1.



Our own country was the first to realize the military importance of the aëroplane, and in 1907 the War Department issued specifications and proposals covering the construction of an aëroplane for the military service. In 1908, in the trials at Fort Myer, Va., due to an unfortunate accident, Lieutenant Selfridge was killed and Mr. Orville Wright injured, and activities were suspended until the following year, when the Wright Brothers demonstrated their machine, which was accepted by the government. Practically nothing was done in this country until after July, 1910, when the first appropriation of $125,000 was available. A few machines were purchased and a few officers placed under instruction at the aviation school at College Park, Md. In 1911 a small aviation detachment was sent to the Texas border at the Camp of Concentration, and a number of reconnaissances made of the Rio Grande frontier. In 1912 they were used in the manœuvres in Connecticut and also for the observation of artillery fire at Fort Riley, Kan. In 1913 they were again

FIG. 2.



sent to the concentration camp at Texas City, Texas, and the school detachment subsequently moved to the present establishment at San Diego, Cal., where the training has been continued and detachments sent to the Hawaiian and Philippine Islands. While the number of officers on this duty has been small and the equipment extremely limited, the results obtained by them, I think, are on a par with anything that has been achieved in the military establishments abroad.

Aviation has appealed to the *esprit* of the French nation in a stronger way than to that of any other nation. The French have led in the development of military aviation perhaps to offset the German superiority in dirigibles. Military aviation in the French Army was in 1912 made a separate arm of the service, it having been under the Engineer Corps. It is directly under the War Ministry, and has a general officer at its head. The personnel is composed of officers and men recruited from all arms of the service, and when the new organization is completed the French Army will be in the possession of twenty-seven field detachments, five fortresses, and six coastal detachments, for which 450 machines and twenty-five dirigibles are altogether available. The service is divided into two branches—that of the dirigibles and that of the aëroplanes. The headquarters of the French aëronautical service is in Paris, and the whole of the military aëronautical establishments in France and Northern Africa are contained in three groups, with headquarters, respectively, at Versailles, Rheims, and Lyons. The field detachments are assigned, as a rule, to the headquarters of the various army corps. The Central Supply Depot and aëronautical laboratory is at Chalais Meuden. The personnel of the flying corps at present is 248 officers and 1374 enlisted men.

The military aëronautical troops of Germany are under the command of a general of division, and the service is divided into that of dirigible balloons and that of aëroplanes, each under a separate head at Berlin. The total personnel is 82 officers and 1458 non-commissioned officers and enlisted men. Germany is divided into three grand groups, the first facing towards Russia, the second towards France, Colmar, Metz, Strassburg and the Rhine, the third constituting the entire central hub near Berlin. These troops are divided into four battalions. The first battalion is located near Berlin and at Dresden, the second at Posen, Graudenz, and Königsberg, the third at Cologne, Hanover, and Darmstadt, and the fourth at Strassburg, Metz, and Friedberg. Bavaria will have a separate battalion. The present aëronautical project calls for an expenditure of twenty millions by the first of January, 1918.

In Great Britain the military aëronautical establishment consists of the Royal Flying Corps, which comprises the central flying school at Upavon, Salisbury Plain, the naval and military wings, the reserve, together with a separate establishment, the Royal Aircraft Factory, and the government aëronautical laboratory. Control of the military policy is under the Air Committee, which is a sub-committee of the national defence committee. The military wing of the Royal Flying Corps is under the newly-created Department of Military Aëronautics in the War Office, while the naval wing is now managed by the air committee of the Admiralty. So far, no one has been appointed to supreme command of the entire flying corps, as was contemplated in the original scheme, although there is at present some agitation for the establishment of an air department, with a responsible head filling the functions of Minister of Aërial Defence.

There are five aëro squadrons in the military wing, three of them located at South Farnborough, one at Montrose, and one at Nethersdon, and eight stations for the naval wing. There are available for service six dirigibles and one hundred and sixty-one aëroplanes. On the first of January of this year all the dirigibles were transferred from the military to the naval wing of the Royal Flying Corps.

Experience has developed three types of aëroplanes for military purposes: The first, the speed scout, for strategical reconnaissance, a one-seater, with speed up to 85 miles per hour and radius of action of 300 miles and a fast climber, about 700 feet per minute; the second for general reconnaissance purposes with the same radius of action, carrying both pilot and observer, and equipped with radiotelegraphy, slower in speed, about 70 miles per hour, and climbing about 500 feet per minute, and in some cases protected by armor; the third, or fighting craft, armored, and carries in addition to the pilot a rapid-fire gun and ammunition, and so arranged as to have a clear field of view and fire in either direction up to 30 degrees from the line of flight, the speed to run from 45 to 65 miles per hour, and the machine to climb about 350 feet per minute.

From the foregoing it is easy to infer what the position of the United States is with respect to air power among the nations of the world. We, who in the beginning started the movement, are now at the tail of the procession. We have no dirigibles, but very few trained men, and fewer machines. The manufacturing industry is moribund from the lack of business, and there is no future for it. We have no aërodynamical laboratories in which to study the problems, and no engineering courses, except one, in which to develop our constructors. The government has not stimulated any advance in the design of machines or motors by competition for substantial reward. We have no National League, as in France and Germany, to assist the government by private subscription and by public demand for the development of air power. The interest of our people in aëronautics at large is dead, and has been perhaps so lulled by a sense of false security and the belief that war will not come to such a vast and powerful nation as ours that it will not heed an oft-quoted maxim of the Father of Our Country, " In time of peace prepare for war." In no particular is it more impossible to make up deficiencies after the outbreak of hostilities than in aëronautics. What is to be done? To call to the attention of our people and of our Congress the exact state of affairs to-day. This can well be achieved through the membership of your institution.

Tests of Hardness Effected with a Hand Device. M. F. TURPIN. (*Revue de Metallurgie,* Feb., 1915.)—While not designed for tests yielding the precise results of laboratory apparatus, this simple device is adapted to determining hardness with a satisfactory degree of accuracy for many manufacturing purposes. It consists essentially of a steel ball protruding from the end of a hollow mandrel backed by a cylindrical slug of known hardness on the Brinell scale. Surmounting this slug, a plunger protruding from the opposite end is provided. In use the ball is brought into contact with the piece to be tested, and the free end of the plunger is struck with a hammer. The indentation of the part tested is then compared with that of the standardized slug. The device is 30 mm. in diameter and about 90 mm. long.

RECENT TENDENCIES IN HIGH SCHOOL CHEMISTRY.*

BY

ROBERT H. BRADBURY, Ph.D.,
Head of the Department of Science in the Southern High School, Philadelphia.
Member of the Institute.

I.

LET me first refer, very briefly, to propositions which affect the position of chemistry in the course and the amount of time devoted to it. On account of the great industrial importance of the science and of the high probability of its being of value to the student after his school days are over there has been a widespread demand that chemistry be started earlier in the course,—*e.g.,* in the second year,—and that two years of it be given. Since chemistry is, at present, usually given only in the fourth year, it follows that approximately two-thirds of the one million high-school students of the country leave with no knowledge of chemistry whatever. This seems an unfortunate method of handling a science which is perhaps the most immediately useful subject of the whole curriculum.

Further, we need continuation courses in the science, because they will improve the character of the work. As Dewey has pointed out, in a memorable essay,[1] the excellent results undoubtedly obtained by the study of Latin in high schools are probably due less to the subject matter of the instruction than to its method. Latin runs through the whole four years. The first-year student knows—or can be effectively convinced—that if he neglects his Latin he will be all at sea in it during his second year. The second-year student has the salutary pleasure of using his first-year Latin [2] as an instrument of further achievement. The same statements hold good, with cumulative force, for the third and fourth years.

Let us follow Dewey a little further in setting up an imaginary linguistic curriculum which shall parallel, as closely as possible, our present arrangements for the sciences. It would run somewhat as follows:

---

* Communicated by the Author.

[1] Dewey, "Science as Subject Matter and as Method," *Science,* vol. 31, p. 121 (1910).

[2] Dewey, *loc. cit.,* p. 124.

"The time devoted to each language is about four hours a week for forty weeks. Latin is finished the first year, French the second, German the third, and Spanish the fourth. Similar courses are offered, as electives, in Greek and Italian."

Supposing that this curriculum were offered, in all seriousness, to a representative group of high-school language teachers, would they accept it? Would the herald who voiced the proposed change escape with his life from the fury he had provoked? And would not the teachers be absolutely justified in their enthusiastic rejection of such a proposition? Yet each science offers to the student a far greater task than each language. An earnest student can obtain, without overwork or hardship, a substantial reading knowledge of French in about three months. This is not the sort of knowledge that will fit one to teach a language, but it is the key of the treasure-house of French literature and French science. How much chemistry or physics can one learn in two months? Why are we so much more generous in our allowance of time to the languages than to scientific subjects?

Finally, it is well to point out that the strong movement to establish a generalized science course in the first year has a very definite bearing upon the question we are discussing. Something like a third of the time appropriated to general science would naturally be spent upon the fundamental conceptions of chemistry, and the ideas thus gained would add greatly to the efficiency of the chemical work of the later years.

II.

We turn now to the consideration of those suggestions which affect the method and subject matter of the chemical teaching. Here the chief tendency that calls for comment is a somewhat insistent demand that the "theory" be cut out of the courses, that the work be made more practical, or that the subject be "brought close to the lives of the pupils."

Sir William Hamilton, with his usual penetrating insight, remarks that the "word theory is used in a very loose and improper sense by English writers." In fact, the word is often employed with great freedom by people who become embarrassed when they are asked to explain exactly what they mean by it.

Perhaps the most frequent significance attached to the word is that of a hypothesis which, on its way to take rank as a fact, has achieved such a measure of probability that it is entitled to be promoted into a kind of special class of near-facts, so to speak. In order to test this meaning let us glance at an example, adapted from Huxley.

A man is sitting quietly by a window. Various sounds, sight-sensations, and perhaps odors affect him, and, because they do not concern him, he gives them only a languid attention. Suddenly he becomes aware of an odor of wood-smoke. This being potentially a matter which does concern him, he is aroused to attend to it, and thinking begins. This thinking takes the form of constructing hypotheses to account for the odor. His neighbor may be lighting a fire, or some one may be burning brush in the street. These being of no special interest, it does not occur to him to verify them; but a third hypothesis, which flits across his imagination, is of such importance that it must be tested at once. He recalls that, a few minutes ago, he withdrew the ashes from his furnace into a wooden box. The ashes were hot, and he is disturbed by the possibility that the wood has been kindled by a glowing ember.

At this stage he disappears down the stairs, with a speed which can be calculated from the laws of falling bodies, and his subsequent proceedings interest us no more. If he finds the cellar in flames, he can reflect with pride that his hypothesis has withstood the test of experience. True hypothesis, the tadpole, has here, in our presence, acquired legs, dropped his tail, and become a fact, but at what stage was the thing a theory? Did it not remain a hypothesis until, in a moment, it was transformed into a fact?

There is, in the evolution of a tadpole, a stage in which, though he has acquired legs, he unwisely holds on to his tail and functions, for a time, as a gawky monster of most displeasing appearance. This would be the biological analogue of a theory, but I am not aware that a hypothesis, in its transformation into a fact, passes through any stage of this kind.

A second sense in which the word "theory" is used is to designate those portions of a science which cannot be directly employed in earning a living. In that case, cutting out the theory would mean the elimination of the entire curriculum, with the possible exception of certain commercial branches. Other meanings there are in plenty, but we cannot delay to deal with them. Let us rather drop the word altogether, since it seems to have become a mere instrument of intellectual confusion. Hypothesis we know—it means a guess. And fact we know—it means a hypothesis which has proved to be correct. But theory means nothing. It is merely a term which people apply freely to any difficult subject which they do not understand, and of which they cannot grasp the importance.

III.

Looking at the matter from the more positive point of view of the recommendation to make the work more practical, we find, fortunately, that this desire has received concrete expression in several texts, which are worthy of careful study. They begin with a hundred pages of formal chemistry, given in a purely didactic way. This portion is a kind of highly-condensed and abstract grammar of chemical science, and is apparently offered in the hope that the student will be able to apply the principles in the work that follows. The remaining pages are devoted to such subjects as lime, cement, pottery, inks, electric furnaces, pigments, etc. In fact, the books are, to all intents and purposes, elementary chemical technologies.

Here, then, is a definite constructive plan for rendering our work more practical, fully worked out. We have merely to cut down the chemistry to an introductory course, and spend the time upon technology. But, as a matter of fact, is a mass of more or less accurate information about technology likely to prove of greater value to the student than a knowledge of the scientific aspect of the subject? Will he ever need to make his own ink or his own pottery? In the scientific type of text, the student, under calcium carbonate, learns something of the effect of heat upon it, and of the interesting dependence of the process upon the concentration of the carbon dioxide in contact with the solid. Here we have, instead, a two-page description of the manufacture of lime in a rotary kiln. Is not the hypothetical practical character of this kind of knowledge a pure illusion? Of course, the fact that lime is not really made in rotary kilns is an unfortunate accident, but, even if it were, in what way could the student make any actual use of his knowledge of the process?

This leads to the remark that the technology in the texts which feature that subject is apt to be inaccurate. It is most difficult for a text-book writer to be sure of his technology. The technological journals do not speak with the authority of the journals devoted to pure science. They contain numerous articles which are written for advertising purposes, and which must be read with great caution. The real methods by which results are obtained are often carefully kept secret. To quote from a review: "The technology of the average elementary text is a species of museum, in which processes discarded elsewhere are preserved forever, like insects in amber."

But even if the author of a book of this type should succeed in making the technology accurate, it would not long remain so, for technology changes with astonishing speed. I have known chemical manufacturers to object to the permanency of concrete buildings, because their solidity introduced difficulties when it became necessary to "scrap" the plant to keep pace with progress. We should firmly grasp the fact that, in changing from chemistry for technology, we are deserting knowledge of proved permanent worth, to deal in information whose chief characteristic is the evanescence of its value. The technology we teach now will merely mislead our students ten years hence, unless they have been able to keep up with the progress of the subject.

There is another important point which is commonly lost sight of by those who insist that we should confine our teaching to the applications. Technology is simply applied science. "There can be no applied science without science to apply." To teach nothing but the applications would sterilize chemistry and destroy the possibility of progress. The applications themselves would at once stagnate. The disinterested research of to-day is to-morrow the basis of an industrial process, and is directing the production of the luxury or the necessity of thousands. Pure science is the most intensely practical of all human activities. Those who sneer at it are ignorant of history. In about a century it has transformed the conditions of human existence, and its work is hardly begun. It is the only occupation worthy of a man who desires to benefit the world as much as possible by his residence in it. Science is by far the greatest of all the forces working toward the material and mental uplift of the people. A child who gives up four years to a higher education has a right to as much of it as we can give in the time—all too short—at our disposal. And I may digress for a moment to remark that it seems to me little short of robbery to waste his course with chicken-feed of the fruit-spot, ink-spot, grease-spot, garbage-can type—a proceeding which leaves him, at the end, ignorant of chemistry but the fortunate possessor of a few bits of household information, which he could obtain from any intelligent woman in five minutes.

If, then, technology is really no more useful to the student than chemistry; if the technology of those elementary texts which specialize in it is often quite hopelessly inaccurate, and if, even when accurate, it does not "keep," I hold that it would be a bad blunder to eliminate our chemistry and to substitute for it a scrappy mass of information about technical processes. Such a course would be perfectly incoherent. It would have no beginning, no logical development, and no end, and would lead nowhere.

Yet technology has an important place in the course, but its place is subordinate. The wise teacher will vitalize his work by constant brief references to the applications. He will keep the tremendous industrial importance of chemistry continually before his students, but he will do this without discarding the main object. The proposition to omit chemistry from the high-school curriculum, and to substitute elementary technology for it, is merely another instance of that muddle-headed worship of the word "practical" which is the bane of Anglo-Saxon thinking.

IV.

Glancing now at the third slogan, "Bring the subject closer to the lives of the pupils," we must admit that this rather vague expression has a content of fact that is well worth noting. The essence of good teaching is to proceed from the familiar to the unfamiliar, from the concrete to the abstract. Chemical facts are all about us. The beginner has an abundant supply of them stored up from his daily experience, though he does not recognize their chemical character until his attention is directed to the point. It is a matter of first-rate importance to utilize this information, which he already possesses, as a foundation for the structure we are trying to build. This leads to a copious use, especially at the outset, of materials drawn from the daily life of the students. Each subject should be started, if possible, with something familiar and concrete to the beginner.

I admit freely the difficulty of this. Alexander Smith says:

"We cannot possibly confine ourselves to common materials in attempting to teach the science. We simply cannot summon it forth from a mass of information about cooking, agriculture, rusting, and photography by any legerdemain." It is also true that the strength of the appeal depends upon the character of the experience of the student. Professor Whitsit remarks that most of his beginners live in small flats, where everything is operated by push-buttons, and where there is an utter lack of chemical data. Physics is more fortunate than chemistry, so far as this question is concerned.

Admitting these difficulties, the fact remains that the available experience of the beginner is a most important element in the work, and that the teacher's success will be nearly proportional to his ability to appeal to it—to make his teaching homely, rather than didactic and academic. And when there is nothing to appeal to, we have to create new experience with the mineral collection, the lecture experiments, and, best of all, in the laboratory.

Take the subject of the atomic weights, for instance. They are the very foundation of our science. It is the chief peculiarity of chemistry that it achieves simplicity by operating with different weights of the elements, instead of basing its reasoning upon unit weight, as do the other sciences. There is no subject more important than the atomic weights, and none more difficult, if we do nothing but talk about them. But there are at least four atomic weights which can be determined by the beginner in about sixty minutes with the simplest apparatus and with an accuracy of at least one unit. After the student has done this work his difficulty in handling the atomic weights disappears. They have become concrete to him, and he uses them in his calculations with perfect appreciation of their significance.

V.

It is surprising to find that the fundamental axiom of good teaching—from the familiar to the unfamiliar, from the concrete to the abstract—is violated at all points by the order of topics which is still largely in use in presenting chemistry to the beginner. The current order seems, indeed, to lay stress on starting with the unfamiliar, since it begins with such wholly abstract subjects as matter, energy, molecules, and atoms, and since unfamiliar substances are hurled at the student by the dozen at the very outset. It will be obvious that the plan of giving abstract general concepts to the beginner at the start, when they are entirely unintelligible, with the hope of using them later, is foredoomed to failure. Such concepts should be introduced naturally in the course of the work, as the need for them arises, and when the student has the experience which renders them intelligible. And the use of substances strange to the student, as examples of such processes as solution and crystallization, should be avoided. These things can be much better explained by instancing sugar and salt than by bewildering the beginner by references to copper sulphate, potassium chlorate, and carbon disulphide. We are prone to forget that the chemical names, which are so simple and full of meaning to the teacher, are, at the outset, mere bizarre jargon to the beginner. The student must, of course, be made acquainted with these substances, and with many others, but they should not be introduced until the proper stage has been reached for their full discussion. To attempt to explain a new concept, like solution, by referring to the behavior of a totally unfamiliar substance, whose very name the beginner cannot pronounce, is to destroy all chance of comprehension. The more homely the instance the better. The student who has watched the behavior of the sugar in a glass of lemonade has started on the path which leads to the peak whence he can view the territory opened up by Raoult, Arrhenius, and van 't Hoff, in all its spaciousness.

Another bad defect in the usual order of topics is that the earlier part of the work is concerned almost entirely with colorless invisible gases. The only gases the beginner knows are air and illuminating gas, both of which are complex mixtures. Much later in his work, he is profoundly surprised and interested when told that anything so unsubstantial as air can be converted into a liquid. Of a gas as a special form of a single pure substance he has no conception whatever.

At this time the beginner is grappling with ideas which are new and difficult to him, and which are indispensable to his mastery of the subject. The foundation offered to him for the struggle is almost ideally bad. The experimental evidence consists chiefly in changes in the level of liquids in certain graduated glass tubes which the teacher, very wisely, will not allow him to touch. The experiments are impossible in the laboratory, and in the class-room the student cannot read the graduations, and has to take the results on faith.

Take the electrolysis of water. The experiment is dramatic and it always interests the students, but interest, though a necessary condition of success, is not sufficient to it. Question the class a week later. How many have clearly perceived the fundamental fact that every bubble of gas means that an equivalent amount of water has disappeared? This point is in no way brought out in the experiment. Many students imagine, on the contrary, that additional water is formed because of the rise of the level of the liquid in the funnel-tube. How can we explain to them at this stage, or even later, the function of the sulphuric acid? How shall we prove to them that the gases really come from the water, the acid remaining unchanged? And if they are willing to take all this on faith, the only addition to their intellectual equipment is the proposition that when an indefinite and unperceived mass of water disappears two parts of hydrogen and one part of oxygen make their appearance. From this they will at once draw two conclusions:

First.—That water contains twice as much hydrogen as oxygen, whether by volume or by weight is all one, so far as they are concerned, for they do not distinguish clearly at this stage.

Second.—*Therefore* the formula of water is H_2O. Thus they lay the foundation for a comprehensive misunderstanding of the meaning of chemical formulæ, from which it is very difficult to free them later. Ohmann is absolutely right in his contention that this important experiment should be deferred and taken up much later, in connection with sulphuric acid, ionization, and electrolysis.

As a contrast to this, consider the heating, by the student himself, of a gram or so of fine copper wire with sulphur in a closed porcelain crucible. The copper and sulphur have unmistakably vanished. The new gray-black product is visible, tangible, and *weighable,* and the increase in weight happens, fortunately, to be almost exactly one-fourth of the weight of the copper taken. We have, in other words, a rock foundation for the beginner's feet, as compared with a quicksand. A rational order of topics would start with familiar solids like copper, lead, tin, and sulphur. It would settle the all-important question of *combination by weight* before attempting to elucidate the behavior of gaseous molecules, and it would settle this question by experiments which the student could carry out for himself.

It will be seen that the question whether the work should be quantitative or qualitative is one which carries with it its own answer. The laboratory work is not to be regarded as a thing apart. The course has often been compared to a pattern woven of many threads, and most of these threads can only originate in the laboratory, the great object of which is to furnish the sense-experience with which alone the weaving can be accomplished. To make the work all quantitative leads to narrowness, and to serious loss of time. On the other hand, to omit all quantitative experimentation deprives the student of all basis for his reasoning, and introduces almost insuperable difficulties in the way of teaching the subject. As a tentative suggestion it may be remarked that a laboratory course in which one-third of the experiments are quantitative lends itself readily to definite interrelation with the class-room work, and develops good manipulative habits in the students.

The dominant motive in a rational arrangement of the work is the effort to develop each topic out of some concrete familiar instance, so that the matter will be significant to the student from the start. Success depends mainly upon constant attention to this principle. The difficulties in the way have been briefly referred to. Daily life often leaves us in the lurch, but, when this happens, a mineral, or a well-executed laboratory experiment, is an excellent starting-point.

Almost no weight can be attached to systematic chemical classification in the arrangement of elementary work. To group gold and silver with sodium, manganese with chlorine, and chromium with sulphur, hoping that the beginner may reap some benefit later, is a waste of time. Even to the chemist such groupings are not wholly satisfactory, and to the beginner they are altogether artificial and unreasonable. The only families which should receive detailed consideration are those in which the analogies are quite unmistakable, especially the halogens and the alkali metals. The most important task in the reorganization of high-school chemistry is to rid the work of the Procrustean influence of chemical classification, which, after all, is unintelligible without a considerable knowledge of the rare elements. At the end of his course the beginner will not know the names of elements, a rather detailed knowledge of which is essential to the understanding of the classification according to which his work has been arranged. We have come from the universities and taught our students as we were taught and the plan does not work well, for the standpoint of the students and the objects of the work are different.

VI.

In a recent examination for candidates for teacherships in high schools the question was asked whether the *simple* formula H_2O applies to ice, to liquid water, or to steam, with a request for a statement of the reasons for the answer. The effect of this innocent query upon the candidates—university and technical school graduates mainly—was appalling, and the examiner might well have been charged with making the questions too difficult. Yet it is plain that any one who is unable to reply intelligently to this question is in a condition of almost complete ignorance with regard to the meaning of the formula and the foundations upon which it rests.

This is a striking instance of a remarkable peculiarity of chemical instruction, not only in high schools, but in higher institutions. I refer to the stress laid upon subject matter and the neglect of method. Everywhere the object of the work seems to be to give the student a highly-condensed account of the results of the science, without much reference to the method by which its results have been obtained. Whether this is wise or not is a question which deserves much more careful consideration than it has hitherto received. I should be the last to deny the usefulness of chemical information. Yet it is difficult to avoid the conclusion that to most people some conception of scientific method is far more important. The possession of a large amount of information does not alone make a man educated. Education consists rather in the attitude of mind which enables a man to differentiate information from misinformation, and to understand what evidence he ought to require, before giving his assent to a proposition which may at any time assume first-rate importance as a guide to conduct.

This attitude is almost as far removed from mere blank Pyrrhonism as it is from unreasoning credulity. Its chief constituents are a willingness to examine the evidence for any statement, a rooted objection to accepting any statement without evidence, and, finally, the ability to estimate correctly the value of the evidence. It is almost identical with what is commonly called "good judgment," which is a very different thing from technical knowledge. The man who has judgment, but who lacks the specific knowledge necessary to solve a problem which confronts him, can usually make up his deficiency either from books or from other men whose business it is to possess the knowledge which he needs, but the man of wide knowledge, who lacks judgment, will, in spite of his learning, and often because of it, flounder in one disastrous error after another his whole life long.

All of us have known men who, with little technical knowledge, have yet achieved success. The study of such a man will invariably show that, along with aggressive energy, he possesses, in unusual degree, the power to appraise quantitatively the considerations for and against a given course of action. His acquaintances usually recognize the presence of this ability by consulting him about their own problems. And the term "foresight," by which they often designate his special faculty, serves notice upon us that we are dealing with that familiar effort to predict the future from the past which constitutes the pretence of the charlatan, the main business of science, and the chief element of success in common life.

The study of chemistry purely as subject matter is not the best method of acquiring knowledge, and it does absolutely nothing to cultivate the judgment. It may perhaps be objected that such qualities as energy and judgment are innate, but this is merely begging the question. Those who have observed the great development of both energy and foresight which often occurs in a man who is suddenly subjected to new and increased responsibilities will hardly be disposed to assent to the hypothesis of their innateness. How do we know what qualities are innate and what can be cultivated? Perhaps no mental attribute is altogether innate. I admit that the power in question—to marshal the data in an orderly way, to state the problem with precision, and to construct hypotheses which are usually verified by the sequence of events—seems like part of the very fibre of a man's personality, but this is merely because he is using it so continuously that it becomes part of our conception of him. On the other hand, his ability, say, to analyze an iron ore with exactness is only occasionally brought into play, and it impresses us, therefore, as something extrinsic and acquired.

It is interesting, also, to speculate upon the biological aspect of the question. Biologists seem, with reason, to be agreed upon the proposition that acquired characters are not inherited. Assuming that we may invert this thesis, the exceptionally foolish and worthless sons, who often appear in the families of men of commanding ability in financial and industrial directions, lend no support whatever to the assumption that qualities like energy and foresight are innate. And that it is worth while to consider these qualities, in our scheme of science teaching, is indicated by the fact that the men at the helm of all great enterprises—while they may, and often do, possess astounding technical knowledge—are hired chiefly for their foresight, and for their ability to get things done.

I trust that no one will imagine that I am trying to depreciate scientific knowledge. In an industrial civilization, continually growing more complex, the importance of special knowledge is sure to increase, and this is particularly true of chemistry and physics. But it seems to me that to give some attention to scientific method, along with the subject matter, would give our courses coherence and vitality and would greatly increase their interest and value.

Historical Note on Electrolytic Iron. M. L. GUILLET. (*Revue de Metallurgie,* Feb., 1915.)—The commercial manufacture of iron by electrolysis is a problem studied for a very long time, but it is only within recent months that it has reached the field of practical application. About 1860, at St. Petersburg, Klein obtained plates of electrolytic iron for printing bank notes. Klein's bath consisted of a solution containing iron sulphate, 5 per cent., and magnesium sulphate, 5 per cent. This bath worked with feeble current density, 0.1 to 0.3 ampère per decimetre square. It was maintained neutral by the addition of magnesium carbonate. In 1867 Feuquières exhibited in Paris some galvanic deposits of iron, but the process employed was never divulged. At Aix-la-Chapelle, in 1881, Classen devised a method of preparing iron electrolytically by employing a solution of the double oxalate of iron and ammonia with an insoluble platinum electrode. This process has remained an exclusively analytic one. In 1900 the house of Merck, in Germany, secured a patent (German patent No. 126,839) based on the electrolysis of pure ferrous chloride in highly-concentrated solution. A temperature of 70° is requisite, and a current density of 3 or 4 ampères per decimetre square. In America, in 1904, Burgess and Hambuechen succeeded in preparing considerable quantities of iron by electrolysis of a bath based on sulphate of iron and ammonia, the temperature being kept at 30° and the current density at 0.2 to 0.3 ampère per decimetre square. These processes had for their main object the refining of iron, but were not applied commercially. At about the same period Professor Foerster, of Dresden, in collaboration with his students, made several researches on electrolytic iron. These studies are outlined in a publication entitled *Electrochemical Properties of Iron* (edited by Knapp, at Halle). Professor Foerster obtained the best deposits with a solution of iron sulphate maintained slightly acid at a temperature of 95°, the current density being about 2 ampères per decimetre square. In 1897 Cowper-Cowles obtained a patent for the use of a solution of sulphocresylate of iron of 20 per cent. and attempted to produce directly seamless tubes by employing a rotating cylindrical cathode. This process, analogous to the Elmore process for copper tubes, has remained in the laboratory stage and has not given practical results. In Germany, in 1909, Professor Fischer, of Berlin, and the works of Langbein Pfanhauser, at Leipzig, obtained a number of patents relating to the electrolysis of iron. German patent No. 212,994 prescribes the use of very concentrated solutions of iron chloride and calcium chloride working at a temperature of 110° and a current density of 20 ampères per decimetre square. Although this process excited widespread interest, it is not known whether its commercial application has been realized. In any event, it is not intended for the direct production of thin plates; it would appear that the process is applied to the production of more or less imperfect rough plates which are subsequently rolled to size. The process is, therefore, in great part, mechanical. Beginning in 1910, a company, under the name "Le Fer," at Grenoble, secured a number of patents for the electrolysis of iron. These patents are based upon the use of a rotating cathode in a neutral solution of ferrous salts maintained neutral by circulation of the liquid about the iron surface. Moreover, the bath receives periodic additions of a depolarizer, such as oxide of iron, with the object of eliminating—at least in part—the hydrogen which collects on the cathode and injures the deposit when it accumulates in too great volume. With this arrangement it is possible to employ high current density (1000 ampères per square metre), and an excellent quality of iron is produced. The patents of the "Le Fer" company cover the production of *very pure iron,* comparable with the high-quality Swedish irons, either *in the form of tubes or plates obtained directly by electrolysis in the finished state.* This process has passed the laboratory stage and is actually commercial. An option on a license to manufacture these tubes and plates has been secured by the works of Bouchayer and Viallet. An exhibit of commercial tubes has been displayed at the Exposition of Lyons by the latter firm, which is completing the erection of a large mill for the manufacture of this product.

An illustrated account follows, giving at length data on the finished product and technical detail of its manufacture.

LOSS OF WEIGHT OF MUSK IN A CURRENT OF DRY AIR.*

BY

CHARLES B. BAZZONI, A.M., Ph.D.

Many attempts have been made to determine the smallest mass of an odorous substance that can excite the sense of smell. These investigations have been suggested by the assumption that the sensation of smell is stimulated by the direct impact of the particles of matter on the olfactory tract and have had for their ultimate purpose the formulation of a satisfactory theory of smell causation. We may say, in passing, that the questions as to how smell sensations are produced and as to how different odors are related or differentiated are still open. The number of facts known is not sufficient to justify the formulation of a theory. It is interesting to refer to the well-known work of Fischer and Penzoldt,[1] who found that 1 part of musk in 10,000,000 of air and 1 part of mercaptan in 50,000,000,000 of air could be detected, and to that of Passy,[2] who detected 0.000005 gramme of musk in a litre of air, 0.005 mg. of camphor, and 0.00000004 mg. of mercaptan.

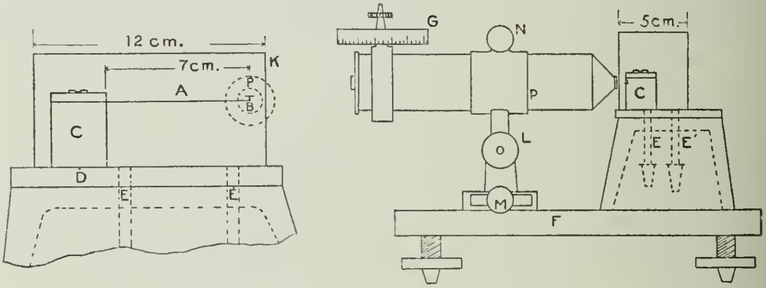
It seems fair to assume that the primary sensation is due to particles of the material carried by the air into the nose, and to consider certain, therefore, that all odorous materials must constantly lose in weight. The results of Passy seem to show that the loss even of strongly odorous substances need not be very great and might consequently be hard to detect and harder still to measure. The attempt has been made several times to measure this loss, using musk. As a result of these attempts it has been stated not infrequently that this substance gives off its odor during years without losing at all in weight, but any one familiar with the hygroscopic character of musk granules will realize at once that a small loss might be completely masked unless extraordinary precautions were taken. In the investigation here recorded the loss of musk has been detected and measured with some accuracy. It must be remembered, however, in dealing with musk granules, that this material is composed of a complex mixture of organic compounds—blood, hair, and sebaceous substances—in themselves complex and subject to evaporation, the products of which may or may not be odorous. Further, since the "odor" or the small odor-producing particles may not constitute all of the loss of weight, or, indeed, excepting by presumption, any of it, the results of these experiments can not be applied directly in the formulation of any theory of smell causation. A proper physical method for the differentiation and classification of smells must apparently involve a study of the physical character of the molecules or molecular aggregates suspended in odorous vapors. This necessitates an investigation of a high order of difficulty which has been undertaken in this laboratory, but which has, so far, produced no very significant results. It is to be observed that loss-of-weight experiments made in this connection have their main significance as studies of solid evaporation.

---

* Communicated by Dr. Joseph S. Hepburn.

[1] *Sitzungsberichte der physikalisch-medizinischen Societät zu Erlangen,* 1885–1886, xviii, 7.

[2] *Comptes rendus de la Société de Biologie,* 1892, xliv (ix Serie, iv), 84.



FLEXURE MICRO-BALANCE NO. 1. C. B. BAZZONI.

A. Quartz fibre.
B. Glass pan.
P. Micrometer microscope.
E. *E'*. Inlet and efflux tubes.
D. Plate glass base.
K. Glass case.
C. Brass pillar.
M, *L*, *N*. Lateral vertical and longitudinal microscope adjustments.
G. Micrometer head.
F. Cast-iron base.

In the investigation here recorded a special form of microbalance was devised to meet the particular requirements. A quartz fibre with a very light pan of thin glass cemented on the end of it was rigidly supported in a horizontal position inside a small glass case. The musk was placed on the pan and the changes in flexure of the beam, which, of course, accompanied the changes in weight, were measured by means of a reading microscope placed outside the case. It is evident that when small loads (0.5 mg. to 1 mg.) are under investigation a very high sensibility may be obtained by selecting a fibre sufficiently thin and a microscope sufficiently powerful. Practically the limit is set by disturbances due to vibrations from external sources and by drift phenomena due to viscosity or to fatigue and to temperature changes in the fibre. These difficulties are, of course, tremendously magnified by the use of very thin fibres or of powerful microscopes. The drift phenomena have been studied separately and have yielded results of some interest, now in course of preparation for publication under the title of "Elastic Hysteresis and Fatigue in Glass and Quartz Fibres." The micro-balance here described was easily usable on an ordinary heavy table, and, when provided with fibres of approximately 0.13 mm. diameter, had a sensibility of 0.00000007 gr. per head division. This means that a loss of weight of 0.00007 mg. in the load on the pan caused a rise of the pan measurable by a rotation of one head division of the micrometer screw on the microscope. A sensibility of 0.00001 mg. was reached by using a thinner fibre. It will be remembered that the sensibility of the best analytic beam balances does not exceed 0.05 mg. per scale division. The details of construction are apparent from the diagram. The base *F* was of massive cast iron, to cut down disturbing vibrations. The glass base plate *D* was perforated, and into the holes tubes were cemented, terminating in ground-glass cones. The case could be evacuated or filled with any desired gas, or a current of gas could be maintained through it. The stiffness of each beam was measured by determining the flexure under known loads. When the constant thus determined is multiplied by the shift of the fibre measured in head divisions we have the change in weight of the specimen.

This balance is obviously well adapted to the solution of this particular problem, in which a small quantity of material undergoing relatively small and slow changes in weight must be kept under observation for a long period of time. Although no great skill is required to manipulate the instrument, it must be remembered that any shifting of the load along the axis of the beam will, unless corrected for, produce a marked error in the results. With one particular beam a shifting of a one-milligramme weight through 1 mm. caused a change in the flexure of 0.061 mm., indicating apparently a change in weight of 0.14 mg. Further, in the interpretation of the results grave errors will occur unless allowance is made for both fatigue and hysteresis, which differ for different beams and with the temperature of any given beam, and which must be determined by experiment for each beam. This balance has, subsequent to the date of this investigation, been modified in many details in order to make it more suitable to work on solid evaporation. For general micro-gravimetric work the triangular beam quartz micro-balance of Steele and Grant,[3] though more difficult to manipulate, is nevertheless to be recommended.

A number of series of observations on loss of weight of musk were run with the balance above described during the years 1912 and 1913. The figures for a single series are given below. In this determination dried air was aspirated through the case constantly. Preliminary series showed that with the tubes open to the outside air the changes due to the alternate absorption and evaporation of water completely masked the changes in weight due to the evaporation of the musk itself. The beam merely rose and fell irregularly, with a period ordinarily of several days, depending on the humidity. (Refer to the results for Experiment A.) When the case was filled with any gas and then closed the beam acted as if the load neither lost nor gained. The phenomena of solid evaporation are, naturally, closely analogous to those of liquid evaporation. In a closed space a saturation density is reached more or less rapidly, and beyond this point evaporation, reaching a steady state, apparently ceases. With a modified form of this apparatus determinations of the saturation densities of the vapors of certain solids as functions of temperature were made subsequently and are now being prepared for publication. It is apparent that a steady loss of weight due to evaporation, odorous or otherwise, can be determined only when the material is in a current of dried gas.

RECORD.

Preliminary.—The beam under a load of 1 mg. showed as a mean of ten determinations a flexure of 4.33 mm. per mg. Each head division of the micrometer was equivalent to 0.00003 mm., wherefore one head division change was equivalent to a weight change of 0.00007 mg.

---

[3] *Proceedings of Royal Society of London,* Series A, 1909, lxxxii, 580.

Experiment A.

1.0436 mg. musk on pan. Musk not dried. Temperature, 18° to 20°C. Tubes open to the air.

1912.	October 24, 12 M.	0	
	4 P.M.	150	h. d. down.
	25, 4 P.M.	140	h. d. down.
	26, 2 P.M.	273	h. d. up.
	5 P.M.	20	h. d. up.
	27, 9.30 A.M.	93	h. d. up.
	28, 9 A.M.	290	h. d. down.
	2 P.M.	35	h. d. down.
	(Current of dry air started.)		
	6 P.M.	1250	h. d. up.
	29, 9.30 A.M.	450	h. d. up.

This specimen continued to lose weight at a lessening rate for several days. It was then accidentally knocked off the pan and a new series had to be started. Observe here the disturbing action of absorbed moisture.

Experiment B.

1.32245 mg. of musk, previously dried in an oil oven, on the pan. Current of dried air flowing steadily and slowly through the case.

		Hours	H. d. change	Loss in weight
1912.	November 1, 12 M.		0	
	2, 9 A.M.	23	66 up	.00462
	3, 10 A.M.	25	68	.00476
	5, 9 A.M.	47	138	.00966
	6, 9 A.M.	24	60	.00420
	7, 9 A.M.	24	62	.00434
	9, 9 A.M.	48	126	.00882
	10, 10 A.M.	25	54	.00378
	12, 9 A.M.	47	110	.00770
	13, 9 A.M.	24	48	.00336
	14, 10 A.M.	25	51	.00357
	15, 9 A.M.	23	48	.00336
	16, 11 A.M.	26	47	.00329
	18, 9 A.M.	46	88	.00616
	20, 9 A.M.	48	84	.00588
	24, 10 A.M.	97	142	.00994
	25, 9 A.M.	23	32	.00224

		Hours	H. d. change	Loss in weight
	December 3, 10 A.M.	193	207	.01449
	8, 9 A.M.	119	106	.00742
	10, 9 A.M.	 48	40	.00280
	15, 9 A.M.	120	90	.00630
1913.	January 6, 9 A.M.	628	397	.02779
	7, 9 A.M.	 24	15	.00150
	8, 9 A.M.	 24	13	.00091
	9, 9 A.M.	 24	13	.00091
	15, 9 A.M.	144	72	.00504
	25, 9 A.M.	240	97	.00679
	February 10, 9 A.M.	348	126	.00882
	14, 9 A.M.	 96	27	.00189
	25, 9 A.M.	264	58	.00406
	March 7, 9 A.M.	264	55	.00385
	10, 9 A.M.	 72	14	.00088
	20, 9 A.M.	240	43	.00301
	April 6, 9 A.M.	408	42	.00294
	15, 9 A.M.	216	17	.00119
	25, 9 A.M.	240	18	.00126
	26, 9 A.M.	 24	2	.00014
	May 8, 9 A.M.	288	5	.00035
	15, 9 A.M.	168	3 down	
	20, 9 A.M.	120	4 up	.00028
	24, 9 A.M.	 96	2 down	

Total loss of weight, 0.18941 mg.
Per cent. of total weight comprised in loss, 14 per cent.

Rate of loss, in mg., per day for each month:

November	December	January	February	March	April	May
.00318	.00135	.00087	.00035	.00025	.00017	.00002

Per cent. of total loss in each month:

November	December	January	February	March	Apri	May
53+	22+	14+	5+	4+	2+	0.3+

On this date the series was discontinued, and the musk, after being removed from the case, was subjected to microscopic examination. The surface seemed somewhat altered in appearance, being more dense or glazed than on a fresh granule, but the general form and apparent size were unchanged, so far as could be judged. No odor was perceptible even after crushing and exposing to the air for forty-eight hours. Moistening did not restore the odor. The granules, when introduced into the çase at the beginning of the experiment, had a very distinct odor. Before introduction into the balance case these granules had been heated in an oil oven at 120° C. for five hours in order to expel all moisture.

One important point has not been mentioned. The air drawn through the case was dried chemically[4] by aspiration through $CaCl_2$, H_2SO_4, P_2O_5 and KOH in large U tubes in the order named. The air current was maintained by a water aspirator and had a low velocity. It is not impossible that the air passing through the case contained chemical vapors which may have acted on the musk. This is a possible source of error, but on account of the low velocity of the air and of the order in which the drying agents were placed it does not seem a real one. Errors due to elastic fatigue were not corrected for in this series. These fatigue effects, however, would always be evidenced as an apparent gain in weight. It should be observed that a stationary beam means a balance of loss in weight against the droop due to viscosity, but this droop becomes negligibly slow after 12 or 15 days, as is demonstrated in the paper on "Elastic Hysteresis," previously referred to. The room temperature ranged between 18° and 20° C. throughout the observation periods, so that temperature effects ought not to have been noticeable.

These results seem to justify the following conclusions: Musk does lose weight when exposed in a current of dried air. This loss is not due to the evaporation of water. After the loss of weight has ceased the musk is no longer odorous. The odor is not restored by exposure to moist air.

In concluding it is desired to point out that the loss of weight here measured is recognized to be due merely to the loss by evaporation of the volatile constituents of this particular specimen of musk. Further, the per cent. of volatile constituents must almost certainly be different in different samples, since musk as it occurs commercially is a complex variable mixture. Also, since the rate of loss must be dependent largely on the relative distribution of the volatile and non-volatile portions of the granule, this rate must be expected to be variable for different granules and irregularly variable during evaporation from any one granule.

RANDAL MORGAN LABORATORY,
University of Pennsylvania.

---

[4] Glass beads wet with sulphuric acid were used. The other reagents were used in solid form.

Stream Gauging and Hydraulic Science. (*Water-supply Paper 375-C,* United States Geological Survey.)—In the great advance which applied science has made in the last generation a prominent member of the vanguard has been the stream gauger—the measurer of the volume of flowing water. His rapid progress is even more notable when it is considered that his work was born hardly a generation ago. In 1889, the United States Geological Survey began investigation of the water resources of the country, and so little work of that kind had previously been done that the beginners felt that they were entering an entirely new field of research. Owing very largely to contributions of the engineers of the United States Geological Survey, stream gauging has developed empirically and scientifically until it comprises a field of classified knowledge which well entitles it to a dignified place among the sciences. As a science it is a subclassification of that longer recognized and more inclusive science of hydraulics. Knowledge of it is required in practically all branches of engineering, and it is being taught as a regular course in many of the leading scientific schools. The relation of stream gauging to the science of hydraulics, stream gauging as a science, and the probable future developments are discussed briefly in a report by C. H. Pierce and R. W. Davenport, recently issued by the Geological Survey as Water-supply Paper 375-C.

In regard to future developments the authors say: "It seems probable also that in the future the results of accurate stream gauging will be utilized in connection with problems in meteorology and physiography. Although the determination of better coefficients for use in the accepted hydraulic formulas and the deduction of new laws not heretofore expressed may be confidently expected, it should also be remembered that the results of stream gauging have already been applied to the measurement of rainfall on a large scale and to problems involving no less complicated features than the determination of effects of deforestation on the navigability of interstate streams."

A New Crystalline Variety of Silver. T. C. CHOUDHRI. (*The Journal of the American Chemical Society,* vol xxxvii, No. 9, September, 1915.)—Spongy silver, prepared by igniting pure silver tartrate, was treated at the ordinary temperature with strong nitric acid (sp. gr. 1.42) from which lower oxides of nitrogen had been removed by boiling with carbamide. At first some action took place with the formation of silver nitrate and nitrous acid, but after a time the solution of silver stopped, and on allowing the mixture to stand with occasional shaking for about two weeks, the remaining silver was converted into long, needle-shaped crystals easily visible to the naked eye; slender needles which when first formed appear floating on the acid liquid. This is considered to be a new variety of crystalline silver belonging to the cubical system.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

STANDARDS FOR ELECTRIC SERVICE.

[ABSTRACT.]

ELECTRIC light and power companies are now subject to regulation by State commissions in more than half of the States of the Union, and by municipal ordinance in a number of cities in States not having commission regulation. The supplying of electric service to the public is largely a monopoly, and regulation on behalf of the public is generally considered necessary and economically advantageous.

Owing to the very rapid development and constant changes in methods and apparatus, it has heretofore been difficult to fix standards for electric service for general adoption. Developments are, of course, still going on, but the methods of electrical distribution and measurement in common use, and the criteria of good service generally accepted, have become so largely standardized by practice that it is now possible to formulate standards of service that will be generally acceptable.

The popular movement for the regulation of public utility corporations has spread rapidly since 1907, and at present there are corporation commissions, public service commissions, or railroad commissions in every State save two. In the States of Arizona, Connecticut, Illinois, Indiana, Missouri, Montana, New York, New Jersey, New Hampshire, Nevada, Pennsylvania, Oregon, Washington, West Virginia, and Wisconsin and the District of Columbia orders and rules for the regulation of electrical corporations have been issued by the commissions. Similar rules are under consideration in several other States, while a few commissions have so far issued only certain recommendations. Circular No. 49 of the Bureau of Standards discusses the most important factors constituting and promoting safe and adequate electric service, the circular being based on a careful study of the experience of operating companies and regulating bodies, both State and municipal. The circular contains, first, rules and recommendations for the regulation of electric service companies by State commissions; second, three different ordinances suitable for adoption by towns and cities in States not having regulation by commissions; third, specifications for the approval of types of electricity meters by commissions; and, fourth, all orders, rules, and regulations so far adopted by commissions for electric service.

---

* Communicated by the Director.

The rules suggested as suitable for the consideration of State public service commissions are the result of conferences and correspondence with nearly all of the commissions, and careful study and comparison of existing orders and rules.

The suggested regulatory ordinances for electric service in cities are based on a very careful study of the subject and conferences with many operating companies and others qualified to express opinions. Ordinances regulating electric service are so far in force in a very few towns and cities, and in most instances are limited in application to meter inspections and tests upon customers' complaints. Three different ordinances, varying in scope and length, so as to make them useful to municipalities of all types, from small towns to the largest cities, are proposed and discussed. It is believed these suggested ordinances will be of considerable interest and value to municipal authorities in cities and towns situated in States not having commission regulations of electric utilities.

A brief description of the electrical testing equipment provided by each State commission for the calibration and standardization of " working test standards " used by central stations in their meter work, and for making tests on customers' meters upon complaint to commissions, is of interest to operating companies, and particularly to commissions considering the equipment of similar laboratories.

In appendixes are reprinted certain sections of State public service commission laws, relating particularly to the regulations of electric service as to adequacy and safety, and, in addition, tables and summaries on various phases of voltage regulation, meter testing, and general central station statistics.

The Bureau asks for criticisms and suggestions from operating companies, commissions, State and city inspectors, committees of associations and engineering societies, and all others interested in the establishment of proper standards for electric service.

DIFFERENCE IN WEIGHT BETWEEN RAW AND CLEAN WOOLS.

By Walter S. Lewis.

This investigation was made (1) to obtain some definite knowledge as to the shrinkage of some of the foreign raw wools imported into this country, (2) to ascertain the shrinkage variation in two samplings of the same fleece, and (3) the difference in shrinkage between two fleeces of the same breed of sheep which were grown in the same section of country. The term "shrinkage" as used here means the total loss, by weight, of all grease and dirt. This elimination of grease and dirt was accomplished by first scouring in a warm solution of pure olive-oil soap and then extracting the remnant grease with ether; the loss is therefore the shrinkage, and pure wool fibre remains. In commercially scoured raw wool there remains from 1 to 3 per cent. of the wool grease, therefore to arrive at the shrinkage which would obtain in ordinary mill practice from 1 to 3 per cent. must be subtracted from the shrinkage results shown in the tables of this paper.

Conclusions.—(1) Forty-nine fleeces were carefully sampled and thoroughly cleansed of all grease and dirt, the results showing shrinkages from 19.5 to 54 per cent., according to the breed of sheep.

(2) In the South Australian wools the greatest shrinkage difference between two determinations upon samples drawn in the same manner from the same fleece was 3 per cent., while for the New Zealand wools the largest difference was 6 per cent. These differences were calculated on the basis of raw wool weight.

(3) The difference in shrinkage between two fleeces of the same breed of sheep grown in the same location was found to be as great as 9.5 per cent. The results of such tests upon 13 different breeds of sheep showed a mean variation of only 4.5 per cent. in the shrinkage.

PROTECTION OF LIFE AND PROPERTY AGAINST LIGHTNING.

By O. S. Peters.

This paper is a report of a survey of statistical data relating to life and property hazards from lightning, and also of existing methods of protection against lightning. The field covered does not include electrical power and signal systems. In the course of preparation of the paper an examination was made of the available literature on the subjects of lightning phenomena and protection against lightning, and of the reports of fire marshals and insurance companies. In addition to this a considerable amount of data was obtained from the reports of the Census Bureau, and manufacturers of lightning rods were asked to submit their opinions, and the results of their experiences, as to how a system of lightning rods should be installed. Appendixes are included in the paper, giving rules concerning the installation and maintenance of lightning rods which have in some cases been followed in Germany, England, and the United States, and also rules for first-aid treatment in cases of persons injured by lightning.

The chief facts disclosed by the information obtained in the course of the inquiry may be summarized briefly as follows:

(1) The property loss by lightning for the entire United States is approximately eight million dollars per year, of which by far the greater part occurs in rural districts.

(2) During each year there are approximately 1500 persons affected by lightning stroke in the United States, one-third of this number being killed and the rest subjected to injuries which in many cases are permanent. About nine-tenths of these accidents occur in rural districts.

(3) Such evidence as is available on the effectiveness of lightning rods indicates that, taking rods as they come in the general run of installations, they reduce the fire hazard from lightning by 80 to 90 per cent. in the case of houses, and by as much as 99 per cent. in the case of barns. The same is undoubtedly true of other buildings having characteristics similar to those of barns and houses.

(4) With regard to the proper metal for lightning rods, it may be said that the differences of resistivity of the metals ordinarily available for lightning rods are not great enough to make one metal preferable to another. Resistance to atmospheric and soil corrosion is the chief essential to be considered.

(5) Extended metallic masses on or within a building must be made a part of the lightning rod system, with a possible exception, however, in the case of metallic masses within the building which do not come near the roof and are at a distance of ten feet

or so from the rods. Gas-pipes should be avoided in erecting lightning conductors if possible, but if they are so located that it is impossible to keep at a distance of ten feet or more, they should be electrically connected to the rods at several points, connected to earth within the building, and well bonded around the gas meter.

(6) The maximum current in a lightning flash may, in some cases, be more than 20,000 ampères.

(7) Each flash of lightning consists, in most cases at least, of a number of consecutive discharges along the same path, with short time intervals between them. The duration of each of the consecutive discharges is of the order of $\frac{1}{35000}$ second. The best obtainable evidence points to the fact that these consecutive discharges are unidirectional and of steep wave-front.

(8) The heating effects of a lightning stroke on a rod of ordinary size, *i.e.*, a rod weighing about 0.5 kg. per meter, are not likely to be appreciable except at the place where the stroke enters the rod, or at high-resistance joints.

(9) Good mechanical construction in a lightning rod system is a prime essential to permanency. Rods are subject to severe strains from wind, snow, and ice, thermal expansion and contraction; and, in the event of a stroke of lightning, to electromagnetic stresses, so joints must be strong and the rod securely fastened to the building.

(10) The resistance of the earth connection should be made as low as practicable. In practice there is no chance of getting too low a resistance. On the other hand, a resistance which rises above 15 or 20 ohms at any time should be considered as excessively large on account of the potential drop which may possibly be set up in the event of a stroke.

(11) When a system of lightning rods is installed aërial terminals with points should be placed at all chimneys, gables, points, or other projections toward which a stroke of lightning might be directed. This is because a point cannot be relied upon to protect objects other than that upon which it is placed.

(12) Down conductors should be run in such a way that a stroke on any aërial terminal on a structure will have two or more widely-separated paths from the foot of the aërial terminal to earth. One path to earth has been found to be unsafe, and more than two are preferable.

(13) It has been shown photographically that the path of a

lightning discharge may be shifted by the wind as much as 10 metres or more during the period between the initial and final discharge. For this reason it is advisable not to allow too great an expanse of flat roof to be exposed without aërial terminals.

(14) The return on an investment in lightning rods may be expected in two ways: in a sense of personal security from lightning, and in actual security to life and property. The property loss from lightning is not sufficient to cause universal protection against lightning to be a paying investment. Protection against lightning is justified as an investment only where risk to human life is involved, or where the property risk is great enough to make protection against lightning more economical than insurance.

(15) With regard to personal safety from lightning, it may be said that no place to which a person may ordinarily retire can be considered as absolutely safe. The only places which can be considered as closely approximating absolute safety are in a building completely surrounded by a metal network, in a steel frame building, or in an underground chamber. A high degree of safety, however, may be found in a well-rodded building; the next degree of safety is undoubtedly to be found in an unprotected house, which may be considered as far preferable to the open or unprotected outbuildings.

Use of the Flame Arc in Paint and Dye Testing. W. R. MOTT. (*Electrochemical Society,* September 16–18, 1915.)—The white-flame arc at 25 ampères affords light at two feet (60 cm.) distance more intense than summer sunlight, and, unlike sunlight, this white-light is exactly reproducible and available 24 hours in every day. Sunlight varies continually, due to shifting solar position and changing atmospheric conditions. Dyes and paints have generally been tested in sunlight because, until the invention of the high-amperage white-flame arc, sunlight was the most intense light practically available. Some good work has been done with the pure carbon arc; but these are limited in value, the first by low intensity and the second by the source of the action being ultra-violet light, which is often different from the action of ordinary light.

The high-amperage white-flame arc has forced out all other forms of illumination as the cheapest, most powerful source for photo-engraving. It is taking its legitimate field for blue-printing, for photographic studio work, and for laboratory and industrial manufacture of chemicals by light.

NOTES FROM NELA RESEARCH LABORATORY,

THE MODE OF ACTION OF ULTRA-VIOLET RADIATION IN INJURING THE REFRACTING MEDIA OF THE EYE.[1]

By W. E. Burge.

THE refracting media of the eye, cornea, lens, etc., are composed of cells. The most important constituent of the cell is a colloidal material, protein. Egg-white is a good example of a protein. It is known that egg-white is converted into an opaque coagulum on exposure to ultra-violet radiation, just as it is when it is heated to 100° C.

Free swimming unicellular organisms, paramecia, were exposed to the radiation from a quartz mercury burner and observed under the microscope during the exposure. The normal organisms are transparent; those exposed became very granular and opaque. The conclusion may be drawn that ultra-violet radiation injures or kills living cells by coagulating the protoplasm or living material of the cells.

A normal excised crystalline lens was placed between two quartz plates and pressed into a thin layer by squeezing the plates together. By means of a quartz spectrograph the spectrum from a quartz mercury burner was focused on the layer of transparent lens material for 30 hours. At the end of this time it was as transparent as at the beginning of the experiment. However, when the preparation was immersed in a 0.1 per cent. calcium chloride solution four bands of coagulated lens protein appeared where the bands of the spectrum had been focused. These bands are of wave-lengths 249 $\mu\mu$, 254 $\mu\mu$, 265 $\mu\mu$, and 280 $\mu\mu$, respectively.

The further conclusion may be drawn that the short wave-lengths of the spectrum coagulate the living material of the cells by changing this material in such a way that certain salts (*e.g.*, those of calcium) can combine with it to form a precipitate or coagulum, and that the effective wave-lengths in case of the quartz mercury arc used are between 249 $\mu\mu$ and 280 $\mu\mu$ inclusive.

---

* Communicated by the Director.

[1] To appear in *Transactions, Illuminating Engineering Society* and *The Ophthalmic Record*.

The great resistance of the normal lens to the coagulative effect of ultra-violet radiation is accounted for by the fact that normally there are present in the lens practically no salts to combine with the protein changed by exposure to the short wave-lengths of the spectrum to form a coagulum. The fact that it has been possible to produce an opacity of the lens or cataract in fish living in solutions of certain salts by exposure to ultra-violet radiation, whereas this could not be done with fish living in tap-water, would seem to support this hypothesis. Using frogs, it has been shown also that the effectiveness of ultra-violet radiation in producing anterior eye trouble is greatly increased by solutions of the salts of calcium or of magnesium or sodium silicate. These salts were used because quantities greatly in excess of the normal had been found in human cataractous lenses.

"OVERSHOOTING" IN TUNGSTEN LAMPS.[1]

By A. G. Worthing.

IN this work the screen of a Lummer-Brodhun photometer head was illuminated on one side by the lamp investigated for "overshooting," and on the other side by an adjustable comparison lamp. By means of a pendulum device, the circuit containing the lamp being investigated was closed; and then, following a desired heating interval for its filament, the photometer field was momentarily (0.02 second to 0.05 second) exposed to the observer's eye. Repeated trials in adjusting the voltage of the comparison lamp, following a definite cooling interval (about 12 seconds) led to an approximately instantaneous determination of the luminous intensity of the lamp being investigated. Determinations for various heating intervals gave the luminous intensity of the lamp on being lighted as a function of time. Any "overshooting" in luminous intensity and its magnitude may be readily seen from a plat of the data.

A 1.1-mil filament in an evacuated bulb (25 watts, 110 volts) in a 110-volt storage battery circuit showed a slight "overshooting," which may possibly, in the light of some other work, be ascribed to the slower relative rate in the heating of the cooled ends as compared with the central portions of the filament. A 6.5-mil gas-filled lamp with a hair-pin filament showed "overshooting" amounting to about 6 per cent.

---

[1] To appear in *Lighting Journal.*

Taylor's [2] photographic observations have been verified qualitatively, though quantitatively much less of an "overshooting" has been found than one would expect from his work.

Manufacture of Aluminum in the United States. Electrometallurgical Industries as Possible Consumers of Electric Power. D. A. LYON and R. M. KEENEY. (*Proceedings Electrochemical Society,* September 17, 1915.)—All aluminum manufactured to-day is produced by an electrometallurgical process, either by the Heroult process or by the Hall process, both of which are essentially the same. In the United States the Hall process is used, and in Europe the Heroult process.

The production of aluminum in the United States has increased materially since 1912, but exact figures are difficult to obtain (owing to statistics being given for recent years as consumption). The consumption in 1913 amounted to 72,379,090 pounds, of which 23,000,000 pounds were imported during the calendar year. The actual production in 1913 in the United States has been estimated at 65,000,000 pounds and to-day probably 150,000 horse-power is in use for this purpose.

Until recently the production of aluminum in the United States was entirely controlled by the Aluminum Company of America, owners of the Hall patents, which have now expired. On the expiration of these Hall patents in the United States a company was formed by French financiers interested in L'Aluminum Française, under the name of the Southern Aluminum Company. A plant is in course of construction at Whitney, N. C., on the Yadkin River, where a total development in high water of 100,000 horse-power is possible, although the average power will be 45,000 horse-power. The capacity of the plant to be erected will be 20,000,000 pounds of aluminum per annum. This company continued its construction work up to the outbreak of the European war, when it became embarrassed by the then existing financial condition and so was obliged to discontinue its work. Such being the case, the Aluminum Company of America is the only real producer. Some second quality material is put on the market by concerns which simply re-melt scrap and junk.

In Europe the aluminum industry has progressed as rapidly as in the United States. Europe, in 1913, produced about three times as much as the United States, but this country leads in individual production, with France second.

---

[2] *Elec. World,* 51, pp. 859 and 1046, 1908.

Some Facts About Limestone. (*United States Geological Survey Press Bulletin No. 233,* September, 1915.)—A ton of absolutely pure limestone would burn to a little over half its weight of lime, or about 1120 pounds, which, counting 80 pounds to a bushel, would give 14 bushels of lime to a ton. The weight of the burned product, however, generally averages more than this, owing to impurities in the limestone and also because in ordinary kilns the combustion is not complete enough to drive off all the carbon dioxide.

A cubic foot of limestone averages in weight from 145 to 175 pounds, which would make a ton of limestone contain from 11 to 14 cubic feet.

The Thermo-electric Properties of Carbon. W. C. MOORE. (*The Journal of the American Chemical Society,* vol. xxxvii, No. 9, September, 1915.)—This study of the thermo-electric properties of carbon offers evidence from a new viewpoint that amorphous carbon is not a single definite substance. The thermo-electric properties of this material are reproducible for any one carbon, but they may vary with the temperature and are determined by the kind of raw material used and the manufacturing history of the carbon. The fact that with some varieties of arc carbons a considerable temperature range of constant electromotive force was found indicates the possibility of a transition interval for these carbons.

Recent Improvements in the Electric Lighting of Steam Railroad Cars. R. C. LANPHIER. (*Proceedings of the American Institute of Electrical Engineers,* vol. xxxiv, No. 8, August, 1915.)—This paper deals with the axle system of electric lighting for steam railroad cars, and describes recent improvements in control systems for obtaining proper voltage from the generator under all conditions and proper regulation of battery charge to conserve the life of the storage battery. Methods of control depending upon *voltage* of the battery have not been successful. Since the beginning of 1914, extensive use has been made of systems of control of battery charge based upon the actual input and output in ampère-hours, and one such system which has proved successful is described.

In the development of the system of control by ampère-hour meter, tests were made by means of a special graphic recording ampère-hour meter which gives a complete record of the treatment received by a storage battery with any axle generator system. Actual records from long runs are reproduced to show the results obtained in the operation of the system of control of charging by ampère-hour meter. With this system the battery has minimum work to do, in most cases operating between points of 75 or 80 per cent. of full load and full charge, and the lighting load is put on the generator as much as possible.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

ARTIFICIAL ILLUMINANTS FOR USE IN PRACTICAL PHOTOGRAPHY.

By C. E. Kenneth Mees, D.Sc.

[ABSTRACT.]

ARTIFICIAL illuminants can be used in negative making for portraiture, cinematograph work, and photo-engraving. For portraiture diffused sources are necessary, and either a large source, such as that given by a bank of Cooper-Hewitt lamps, must be used or the light must be reflected from a large area.

In cinematograph work about a quarter kilowatt per square foot of stage is used, the usual arrangement including the use of Cooper-Hewitt lamps overhead and at one side of the stage, and arcs in front.

For photo-engraving an arc lamp is hung on each side of the copy-board, most engravers using flame carbon arcs.

For printing papers the enclosed arc is used for silver papers, while for platinum the Cooper-Hewitt lamp is satisfactory. In printing fish-glue on metal it is important that a small source of light should be used in order to get sharp definition of the dots, and the printing should be as far away as possible.

The following illuminants are recommended for portraiture: flame arcs, Cooper-Hewitt lamps, and nitrogen tungsten lamps; for cinematograph work, the Cooper-Hewitt, quartz arc, and flame arc; for photo-engraving, the enclosed arc and flame arc; for silver printing, the enclosed or flame arcs; for platinum printing, the Cooper-Hewitt lamp.

The photographic efficiency of artificial illuminants depends upon their quality and upon their visual efficiency, but must be considered from the point of view of the materials used, which materials are of three chief kinds: (1) panchromatic materials sensitive to the whole spectrum and used with filters to give a rendering similar to that seen by the eye, or for color photography; (2) ordinary materials having their maximum sensitiveness in the blue-violet; (3) materials sensitive only to the ultra-violet.

For panchromatic materials the efficiency of the illuminant will

---

* Communicated by the Director.

depend almost entirely upon its visual efficiency, while for ordinary materials the chief point of importance is the efficiency in the blue-violet, but, since the latitude and freedom from halation increase with shorter wave-lengths, it is better to use light sources having their maximum near 400 $\mu\mu$ rather than near 470 $\mu\mu$. It is pointed out that nearly all artificial illuminants have application in some branch of photography or other.

Research Laboratory,
September 14, 1915.

THE RETINAL SENSIBILITIES RELATED TO ILLUMINATING ENGINEERING.[1]

By P. G. Nutting, Ph.D.

The fundamental principles of good lighting are derived primarily from the properties of the human retina, the eye being the sole means of judging whether illumination is good or defective.

Of chief importance is the magnitude of the brightness sensation as a function of the flux density of light at the retina. This cannot be directly measured, but sensibility, its derivative, may be readily determined at all working intensities and formulated in the function

$$S = S_m + (1 - S_m)(B/B_o)^n$$

For threshold sensibility $S_m = 000022$, $B_o = 0000017$ millilamberts, and $n = 0.49$ for white light. For photometric sensibility (König's data), $S_m = 0.0175$, $B_o = 0.0090$ (unit 0.0036 m.l.) and $n = 0.45$. These formulæ for sensibilities integrate into the luminous sensation scale

$$L = K \log \left(1 + S_m(I^n I_o^{-n} - 1)\right)^{1/n}$$

In practical engineering problems interest is centred on four chief levels of brightness. For these the important data are the following:

	Mean brightness level (millilamberts)	Photometric sensibility	Threshold (millilamberts)	Relative sensibility Threshold	Relative sensibility Contrast	Relative sensibility Glare
1. Exterior daylight ...	1000	0.0175	0.35	1	1	1
2. Interiors in daylight	10	0.030	0.017	21	59	200
3. Interiors at night ...	0.1	0.123	0.0014	251	1430	18000
4. Exteriors at night ..	0.001	0.79	0.00011	3090	22300	160000

---

[1] Abstract of a paper delivered at the Washington Convention of the Illuminating Engineering Society.

The numbers of the last three columns are inversely proportional to the threshold, contrast, and glare lumens.

The rates at which sensibility changes from one level to another have been redetermined with improved apparatus for a number of subjects with results agreeing with previous data summarized in Helmholtz, "Physiolog. Optik," 3d Edition. Great attention has been given to determining the rate during the first few seconds of adaptation.

The size of pupil in a normal eye viewing a field of given brightness is roughly as follows:

Brightness ($\log_{10}$ m.l.)........	−5	−4	−3	−2	−1	0	1	2	3
Diameter of pupil (mm.)......	6.9	5.8	5.0	4.3	3.8	3.3	2.9	2.5	2.2
Area of pupil	37.4	26.4	19.6	14.0	11.3	8.5	6.6	4.9	0.8

Local adaptation was found to be pronounced with the field limited by a black-lined tube with an iris diaphragm at the distant end and adaptation to a fixed brightness of 0.1 millilambert. The instantaneous thresholds found were:

Solid angle of bright spot.......	6.0	.43	.016	.0026	.00016	.000041
Instantaneous threshold	.0019	.0020	.0042	.0143	.030	.034 m.l.

The angular size of the fovea is 0.016 steradian; no irregularity in the curve is noticeable at this point. The great decrease in sensibility indicates that adaptation is extremely localized and that the eye is not fitted to function properly when only the object viewed is illuminated. This agrees with the known fact that when contrasts are extreme, as in machine shops, a much higher level of illumination is required than in rooms lacking extreme contrasts.

The relative visibility of radiation of different wave-lengths has recently been determined by Ives, by Nutting, and by Hyde. The best data fit the formula

$$V = V_m R^a E^{a(1-R)}$$

in which $a = 181$ and $R = \lambda\text{max}/\lambda$, λmax being 0.555 μ. The value of V_m (Ives and Coblentz) is 0.00140 watt per lumen. The formula holds well throughout all the more luminous part of the spectrum from 0.48 to 0.67 μ. When multiplied by the spectral energy function of a complete radiator or other body and integrated, it gives total light flux density as a function of temperature.

Sensibility to differences in wave-length (hue sensibility) varies considerably throughout the spectrum and from one subject to another. Averaging the data for eighteen subjects gives:

Wave-length	440	455	492	534	581	621	635 μμ
Perceptible difference.	2.47	2.93	1.36	3.34	1.38	3.75	3.00 μμ

The integral of the hue sensibility gives the fundamental hue scale. With the entire spectrum from violet to red taken as 10 units, the values of the scale are:

Hue scale	0	1	2	3	4	5	6	7	8	9	10
Wave-length	396	421	468	485	501	532	560	577	598	635	700

There are in all about 180 just noticeably different hues in the spectrum from violet to red, and about 20 more from red to violet through purple. The amount of white that may be mixed with hues of various purities before it becomes noticeable is approximately as follows:

Per cent. white.........	0	10	20	30	40	50	60	70	80	90	100
Per cent. hue............	100	90	80	70	60	50	40	30	20	10	0
Impurity noticeable	4.7	4.6	4.5	4.4	4.2	4.0	3.7	3.4	3.0	2.5	2.1

There are about 20 just noticeably different steps between pure hue and pure white. The effect is nearly or quite independent of both the hue and the intensity.

Research Laboratory,
September 10, 1915.

RELATIVE PHOTOGRAPHIC AND VISUAL EFFICIENCIES OF ILLUMINANTS.

By L. A. Jones, M. B. Hodgson, and Kenneth Huse.

[ABSTRACT.]

Certain relations exist between the visual and photographic efficiencies of various illuminants when used in connection with the three typical classes of photographic plates. The classification of photographic materials is made from the standpoint of their spectral sensibilities, the three types being ordinary, orthochromatic, and panchromatic. The work is confined to high-speed materials used for negative making, no attempt being made to cover the entire field of sensitive materials.

The method adopted for obtaining the desired results is essentially that used in the determination of plate speeds, and is based upon the fact that if the plate speed is kept constant and the illuminant varied the "inertia" value obtained will be inversely proportional to the relative photographic efficiency of the source.

The photographic efficiency of sunlight is taken as 100 per cent., and the efficiencies of other illuminants are expressed relative to that of sunlight.

Relative photographic efficiency is designated by the symbol E_r, this term representing the ratio between the effects produced on a plate when given equal exposures (measured visually in metre-candle seconds) to sunlight and to another source. Thus, if for a given source $E_r = 50$ per cent., then in order to obtain a given effect on a plate twice as great an exposure must be given when using that source as would be required in case sunlight were used.

The results obtained are shown in Table VII.

TABLE VII.

Source		Photographic materals		
	Visual efficiency $\frac{\text{Lumens}}{\text{Watt}}$	Ordinary E_r	Orthochromatic E_r	Panchromatic E_r
1. Sun	* 150	100	100	100
2. Sky	....	181	155	130
3. Acetylene	* .7	30	44	52
4. Acetylene—Screened	* .07	81	85	89
5. Pentane	* .45	18	28	42
6. Mercury arc—Quartz	* 40.0	600	500	367
7. Mercury arc—Nultra glass	* 35.0	218	195	165
8. Mercury arc—Crown glass	* 37.0	324	275	249
9. Carbon arc—Ordinary	* 12.0	126	112	104
10. Carbon arc—White flame	* 29	257	234	215
11. Carbon arc—Enclosed	* 9.0	175	177	165
12. Carbon arc—"Artisto"	* 12.0	796	1070	744
13. Magnetite arc	* 18.0	106	115	82
14. Carbon—Glow lamp	2.44	23	32	42
Carbon—Glow lamp	3.16	25	35	45
15. Tungsten—Evacuated	8.0	33	41	50
Tungsten—Evacuated	9.9	37	45	53
16. Tungsten—Nitrogen filled	16.6	56	62	70
Tungsten—Nitrogen filled	21.6	64	68	76
17. Tungsten—Blue bulb	11.0	108	99	106
18. Mercury—Cooper-Hewitt	* 23	316	354	273

The values given in Table VII are relative efficiencies on a basis of equality in illumination. Since the photographic efficiencies in terms of energy consumption are of considerable interest, the values obtained have been reduced to that basis and are given in Table VIII.

The inertia values (i) obtained from the original measurements are expressed in exposure units; that is, metre-candle seconds. The luminous flux incident upon unit area (1 square centimetre) at a metre distant from a source of 1 mean spherical candle-power is $\frac{4\pi}{4\pi r^2}=\frac{1}{100^2}$ lumens. This is the value of the luminous flux incident upon a unit area of a surface at which the illumination is 1.0 metre-candle. Then $i_e=\frac{i\text{ (in m. c. s.)}}{100^2}$ is the inertia value expressed in $\frac{\text{lumen seconds}}{\text{cm.}^2}$

Now, if the efficiency of the source used is E (in $\frac{\text{lumens}}{\text{watt}}$), the value remains the same when expressed in $\frac{\text{lumen seconds}}{\text{watt second}}$, $\frac{1}{E}$ is the efficiency in $\frac{\text{watt seconds}}{\text{lumen seconds}}$, and

$$i_e=\frac{i\text{ (in m. c. s.)}}{100^2}\times\frac{1}{E}=\frac{\text{watt seconds}}{\text{cm.}^2}$$

$$i_e=\frac{i\text{ (in m. c. s.)}}{100^2}\times\frac{10^7}{E}=\frac{\text{ergs}}{\text{cm.}^2}$$

i_e is, therefore, the inertia value expressed in ergs consumed at the source per cm.^{2} at the plate. This value is inversely proportional to the photographic efficiency of the source when used on that particular plate. The photographic efficiency may be obtained, therefore, by taking the reciprocal of i_e.

In order to make the results obtained on different plates comparable with each other it is necessary to use some source as a standard. Sunlight is used as before, its efficiency being taken as 100 on each plate.

The values of visual efficiency for many sources were not measured directly, but were estimated from the best available data found in the literature on the subject. Stars indicate the values so obtained. The values tabulated in Table VIII are:

$$E_e=\frac{100\ i_e\text{ (for sun)}}{i_e\text{ (for particular source)}}$$

TABLE VIII.

Source	Efficiency $\frac{\text{Lumens}}{\text{Watt}}$	Photographic materials		
		Ordinary E_e	Orthochromatic E_e	Panchromatic E_e
1. Sun	150	100	100	100
2. Sky	...			
3. Acetylene	.7	0.14	.21	.24
4. Acetylene—Screened	.07	0.037	.040	.042
5. Pentane	.45	0.053	.086	.13
6. Mercury arc—Quartz	40	158	132.0	99
7. Mercury arc—"Nultra"	35	50	46	39
8. Mercury arc—Crown	37	79	68.0	62
9. Carbon arc—Ordinary	12	10.0	9.0	8.5
10. Carbon arc—White flame	29.0	52	45	2
11. Carbon arc—Enclosed	9	11	11	10
12. Carbon arc—"Artisto"	12	62	86	60
13. Magnetite arc	18	12	14	10.0
14. Carbon—Glow	2.44	.37	.52	.68
Carbon—Glow	3.16	.51	.74	.95
15. Tungsten—Vacuum	8.0	1.74	2.2	2.7
Tungsten—Vacuum	9.9	2.41	3.0	3.5
16. Tungsten—Nitrogen	16.6	6.1	6.8	7.7
Tungsten—Nitrogen	21.6	8.9	9.8	11.0
17. Tungsten—Blue bulb	8.9	5.5	5.2	5.6
Tungsten—Blue bulb	11.0	7.8	73	7.9
18. Mercury—Copper-Hewitt	23.0	47	54.2	42

The values of E_r given in Table VII enable us to pick from any group of sources the one giving the greatest photographic efficiency, when used in connection with either of the three typical classes of photographic materials, for a fixed value of the *illumination.* The values in Table VIII, on the other hand, enable us to choose for either class of materials the source that is most efficient photographically, from the standpoint of *energy consumption.*

Monel Metal Mystery. ANON. (*The Brass World,* vol. xi, No. 8, August, 1915.)—The curious action of sea water and steel has caused the junking of a half-a-million-dollar pleasure yacht. Within a month or two much has been written and pictured concerning the auxiliary yacht *Sea Call,* that has had just six weeks of life and has had to be broken up to prevent sinking. The plating seems to have been fastened to the steel frames without the interposition of zinc, as is said to be the successful practice in the navy, and to-day, owing to the violent action of electrolysis, the ship is crumbling apart.

Mils versus Cubic Centimetres. J. P. Remington. (*The Journal of the American Pharmaceutical Association,* vol. iv, No. 8, August, 1915.)—The new United States Pharmacopœia will authorize the use of the word "mils" to replace the word "cubic centimetres," and at first there will be undoubtedly some criticism and comment upon the change. The last United States Pharmacopœial Convention recommended publicity of changes of this kind in order that users of the United States Pharmacopœia would become familiar with the subject in advance.

The use of the word "mil" is not new, but the first use in a pharmacopœia occurred in 1914, when the British Pharmacopœia adopted it, and it is likely that its use will become universal in time, at least in the English language. "Mil" is, of course, the first three letters of the French name originally given to the thousandth part of a litre—millilitre. Very careful experiments by the government physicists have determined the fact that the cubic centimetre is larger than the millilitre by the inconsiderable fraction of 0.000027. In pharmacy, in chemistry, and in applied chemistry this difference is negligible, but every one must have regretted the cubic centimetre blot on the harmony and beautiful simplicity of the metric system.

Search for Tin in America. (*Bulletin 662-B,* United States Geological Survey.)—In view of the interest in an adequate tin supply for the United States and the discussion of the smelting of Bolivian ore on the Atlantic seaboard, and possibly on Puget Sound, the publication by the United States Geological Survey of a special bulletin on tin mining in Alaska is opportune. It is noteworthy, too, that specimens of stream tin were collected by Survey geologists in Alaska in 1900, before this metal was known to occur in the Territory. Soon after that time prospecting for steam tin became active, and two years later a commercial production of tin ore was made.

The Survey was also closely identified with the finding of lode deposits of tin. In 1903, two prospectors brought to Survey geologists in Alaska some specimens of float from Lost River which they thought might be tin ore. All the specimens but one were worthless. From this one the geologists obtained tin by smelting it in a teacup in their cookstove, after which both the geologists and the prospectors went to Lost River and discovered a vein of lode tin. This lode on Lost River has since been extensively mined. Some of the Alaska tin ore has been reduced at Seattle, Wash., within the last two years.

The report just issued presents a review of other work by the Geological Survey and the reëxamination of the more important tin deposits by Geologist Henry M. Eakin.

The total tin production for the period 1902–1914 amounted to 526 tons of metallic tin, valued at $380,000. The Alaskan tin ores have heretofore been shipped for reduction to Swansea (Wales) and Singapore.

NOTES FROM THE RESEARCH LABORATORY, GENERAL ELECTRIC COMPANY.*

RADIOGRAPHY OF METALS.

By Wheeler P. Davey.[1]

A PREVIOUS investigation[2] having shown the possibility of detecting blowholes in steel castings $^9/_{16}$ inch thick by means of radiographs made with a Coolidge tube, the present problem is to get data for determining the length of exposure necessary for any given thickness, and to find the limiting size of air inclusion which can be demonstrated in a given thickness.

It is found that the effective penetration of X-rays at the voltage corresponding to a 13-inch spark gap between points is a little greater than for the 11-inch gap, but about the same as for the 15-inch. The amount of exposure required, however, decreases as the voltage is increased. The clearness of the picture is not appreciably less at the higher voltages, in spite of the apparent opportunity for scattering.

From the darkening of X-ray plates exposed beneath varying thicknesses of metal and at different voltages, the following formulæ are derived, in which E is the exposure required for good results, in milliampère minutes, and X the thickness of the steel in centimetres:

For a 15-inch spark gap:

$$E = \frac{1}{10} \log_{10}^{-1} 0.71X$$

For a 13-inch spark gap:

$$E = \frac{3}{20} \log_{10}^{-1} 0.71X$$

For an 11-inch gap (approximately):

$$E = \frac{3}{5} \log_{10}^{-1} 0.82X$$

---

* Communicated by the Director.

[1] *General Electric Review,* **18,** 795–800, August, 1915.

[2] "X-ray Inspection of a Steel Casting," *General Electric Review,* **18,** 25–7, January, 1915.

By exposures of an air wedge varying in thickness from $^9/_{64}$ inch to 0, between two plates of metal, it was found that an air inclusion 0.021 inch thick could be detected in 1¼ inches of steel or 0.007 inch thick in ⅝ inch of steel.

Radiographs are given showing autogenous welds in ½ inch steel and the difference in appearance between good, underheated, and burned welds, the last exhibiting a porous structure.

Blowholes, slag inclusions, porous spots, etc., may be demonstrated radiographically, though no fluoroscopic screen sensitive enough for direct vision is yet available. The formulæ show that with the voltage now used it is not yet practicable to test in this way thicknesses of steel greater than ½ inch because of the time required. The technic employed is described in detail.

THE MELTING-POINT OF TUNGSTEN.

By Irving Langmuir.[1]

Observations made during the investigation of the characteristics of tungsten filaments in evacuated and gas-filled lamps indicated that the intrinsic brilliancy of solid tungsten, at a temperature just below the melting-point, is about 7200 international candles per square centimetre. This should correspond, according to Rasch's equation, with constants determined by Nernst, and an emissivity determined by von Wartenberg, Coblentz, and von Pirani, to a melting-point of 3540° K. instead of 3200 to 3300° K., which had appeared, from a consideration of the results of previous investigations to be the most probable value.

An analysis of the sources of error in the method used showed no reason to suspect an error greater than 50°.

It was found repeatedly, however, that the presence of minute amounts of hydrocarbon vapors, such as are given off by vaseline or stopcock grease at room temperature in vacuum, not only lowers the melting-point and raises the resistance, but also increases the emissivity. This factor has entered into many of the methods heretofore used.

In view of the lack of agreement in the values given, it was decided to redetermine the melting-point by methods which should eliminate former sources of error.

---

[1] *Physical Review*, 6, 138–57, 1915 (issued in August).

The two methods employed consisted of (1) determining the black body melting-point of large filaments in nitrogen, and obtaining the emissivity from helically-wound filaments of various sizes in vacuum and in nitrogen, and (2) measuring the brilliancy of a surface of molten tungsten and simultaneously determining the brilliancy of the image of a second surface of molten tungsten reflected in the first, thus determining the reflectivity of the molten metal directly.

A pyrometer of the Holborn-Kurlbaum type was used with several nearly monochromatic screens in the eyepiece of the telescope. The equivalent monochromatic wave-lengths for these screens were estimated by direct spectroscopic examination, and also by measuring the relative brilliancy of a large nitrogen-filled lamp with a straight filament, at a series of different temperatures, by means of a Lummer-Brodhun photometer, using the different screens successively in the eyepiece.

The pyrometer was calibrated by first determining the relation of the luminous intensity of the pyrometer filament to the current flowing through it. This was done by means of rotating sectors, and by comparison with the nitrogen-filled lamp photometered through the three screens over the range of temperatures from 1850° to 3040° K.

Next the currents through the pyrometer filament corresponding to several fixed temperatures were determined from the melting-points of gold, copper, and platinum. The pyrometer was also checked by a heavy filament vacuum tungsten lamp previously calibrated against a black body furnace at the melting-points of gold and palladium.

The emissivity of solid tungsten was obtained by determination of the relative brilliancy of the brightest and darkest portions of a helically-wound filament in nitrogen. The best value appeared to be 0.485 or less for $= 0.537$. The emissivity of molten tungsten measured by the method mentioned below was found to be 0.425, and that of the solid distinctly higher. Hence 0.46 was adopted as the most probable value for $\lambda = 0.667$.

The melting-point of short, single, hair-pin filaments in bulbs containing pure, dry nitrogen was determined on the pyrometer by raising the temperature. The nitrogen atmosphere prolonged the life of the filaments at the highest temperature so considerably that it was possible to approach the melting-point very slowly, and the actual melting lasted several seconds. After burn-out the bulbs were opened and the absorption coefficient determined.

The emissivity and melting-point of tungsten were also determined from an alternating arc between tungsten electrodes in nitrogen. At sufficiently high current density the ends of both electrodes formed molten convex surfaces showing multiple reflections of the two electrodes, and could be maintained in this condition for half an hour or more. Repeated measurements of the intrinsic brilliancy of the molten tungsten and of the successive images were made, giving a direct measurement of the reflectivity and black body temperature, the arc being practically non-luminous with an intrinsic brilliancy less than 1 per cent. of that of the electrodes. The emissivity thus obtained was 0.425 for $\lambda = 0.667$, and the true melting-point derived therewith from the pyrometer measurements 3566° K.

The values for the melting-point by the several methods are then as follows:

1. Total photometric method	3540° K.
2. Filaments by pyrometer method	3332° K.
3. Arc electrodes by pyrometer method	3566° K.

A consideration of the probable errors indicates that the best value is 3540° K. ± 30°.

HARD X-RAYS.

By W. D. Coolidge.[1]

The factors determining the hardness or penetrating power of X-rays are mentioned, special emphasis being laid upon the fact that with any given target the penetration depends entirely upon the impressed voltage and increases with it, without relation to the design of tube, vacuum, or current passing. The penetration hitherto attainable has been limited by the difficulty of producing a tube that can be run continuously on very high voltages.

Recent work indicates that with suitable design a hot cathode tube with sufficiently high vacuum can be built to operate at any voltage now available. The present commercial tube can be used on voltages up to that indicated by a 10-inch spark between points. Experimental tubes, modified from this type, have already been run backing up a 20-inch spark, which corresponds to about 200,000 volts, and the penetration is being determined for comparison with X-rays from radio-active substances. Rutherford [2] has pointed out that on the basis of the quantum theory it can be easily shown that 180,000 volts applied to an X-ray tube should give radiations of a penetration equal to that of the hard gamma rays from radium C, which are only half absorbed by 6 cm. of aluminum.

---

[1] *American Journal of Röntgenology,* 2, 723–5, April, 1915 (issued in August).

Rays of this penetration should be of extreme value in connection with the testing of metals as carried out by Dr. Davey, of this laboratory.

In the field of therapeutics it will be possible to get essentially homogeneous rays by filtering, and in this way find out whether rays of a certain frequency are especially suited for any specific purpose.

Wireless Telegraphy for Railroads. J. L. HOGAN, JR. (*Electrical World,* vol. 66, No. 11, September 11, 1915.)—Since the beginning of experiments in wireless telegraphy for railroad service by the Delaware, Lackawanna and Western Railroad in 1913, there has been ample opportunity to prove the value of radio equipments for provision of an emergency telegraph service. When wires fail because of sleet storms, washouts, wreck, or other line-destroying occurrences, it is found not only convenient but extremely valuable to be able to communicate between the main dispatching points of the railroad by means of wireless. On several occasions the Delaware, Lackawanna and Western has averted extended tie-ups by such use of the radio equipments, and, following these practical demonstrations, installations have been made at Hoboken, Scranton, Binghamton, and Buffalo. The Buffalo station at present has receiving apparatus only, pending completion of a new and permanent aërial structure. Hoboken is fitted with a 5-kilowatt Marconi set and has a 400-foot tower supporting the antennæ. At Scranton and Binghamton 2-kilowatt Marconi sets are installed with antennæ hung at an average height of about 175 feet. It is intended that a 400-foot tower shall be erected at Buffalo, so as to permit reliable signalling in both directions between that point and Hoboken. Experiments made between the National Electric Signalling Company's plant at Brooklyn and the Delaware, Lackawanna and Western station in Buffalo have shown that 10 kilowatts of sending power is ample to give good results over the distance of 400 miles under average daylight conditions.

---

[2] *Philosophical Magazine,* August, 1915.

Overhead Electrolysis and Porcelain Strain Insulators. S. L. FOSTER. (*Proceedings of the American Institute of Electrical Engineers,* vol. xxxiv, No. 8, August, 1915.)—There is a slight leakage of current from trolley wires to earth through insulated supports on all overhead construction, which, if not checked, permits a flow of current which gives rise to electrical separation of water into oxygen and hydrogen. The oxygen liberated acts vigorously upon the adjacent metal parts, which in time become badly corroded. This electrolytic action also seems to remove the galvanizing from live metal parts before attacking the iron. A partial remedy for this rusting of live galvanized wire is painting.

This electrolytic effect is also seen to take place over strain insulators when the creepage distance is insufficient. This indicates that a creepage distance proportional to the conditions met must be secured to stop the flow of current around the outside of the insulators. The author concludes that under fog conditions the insulator surface exposed for creepage is insufficient in our present standard devices.

Another form of overhead electrolytic action noticed in electric railway work is caused by the use of dissimilar metals in contact. Sulphuric acid and other fumes in the air and ozone from a nearby ocean are supposed to be the electrolytes that set up a local battery action at these points of contact. The logical remedy for this trouble is to use similar metal in contact. The paper then describes the troubles encountered in San Francisco due to these causes and the remedies that have been applied.

Great Lignite Resources of North Dakota. ANON. (*Northern Pacific Guidebook, United States Geological Survey.*)—Lignite underlies almost all the western part of North Dakota. It is estimated by the United States Geological Survey that the State contains the enormous amount of 697,000,000,000 short tons of lignite in beds over 3 feet thick and within 1000 feet of the surface, and it seems probable that there is workable lignite within this limit under every section of the land in the western part of the State. It is difficult to form an idea of a mass containing even 1,000,000 tons, and hence the figures given above are practically impossible of comprehension, but if the amount is put in the form of a cube a better conception of its magnitude may be obtained. The lignite of the State, if formed into one mass in the compact form in which it lies in the ground, would make a cube 5 miles long, 5 miles broad, and 5 miles high. Such a cube would cover nearly a township of land and would be almost as high as the highest mountain on the globe.

Much of the lignite, although of poor quality and at present used only in a small way, constitutes a vast fuel resource which will in time become of great value, not only to the individual citizens of the State but to the corporations that are seeking power for use in manufacturing or in transportation.

THE FRANKLIN INSTITUTE

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, September 1, 1915.)

Hall of The Franklin Institute,
Philadelphia, September 1, 1915.

Mr. G. H. Clamer *in the Chair.*

The following reports were presented for final action:

No. 2628.—John Underwood and Company's Combined Typewriting and Calculating Machine. Hans Hansen and Frederick A. Hart recommended to the City of Philadelphia for the John Scott Legacy Medal and Premium; the Edward Longstreth Medal awarded to John Underwood and Company.

No. 2636.—Lenker's L-E-Vation Rod. Final action on this report was deferred until next meeting.

No. 2643.—Street Locomotive Stoker. Clement F. Street recommended to the City of Philadelphia for the John Scott Legacy Medal and Premium.

R. B. Owens,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, September 8, 1915.)

RESIDENT.

Mr. John F. McCoy, care of Midvale Steel Company, Philadelphia, Pa.
Mr. David Pepper, Commonwealth Building, Philadelphia, Pa.
Mr. John P. Sykes, care of The Baldwin Locomotive Works, Philadelphia, Pa.

CHANGES OF ADDRESS.

Mr. Joshua L. Baily, 1508 Walnut Street, Philadelphia, Pa.
Prof. W. S. Franklin, Columbia University, New York, N. Y.
Mr. J. M. Gazzam, 265 South Nineteenth Street, Philadelphia, Pa.
Prof. I. M. Rapp, Department of Physics, Ursinus College, Collegeville, Pa.

NECROLOGY.

John T. Morris, Philadelphia, Pa.

LIBRARY NOTES.

PURCHASES.

BRAGG, W. H. and W. L.—X-rays and Crystal Structure. 1915.
BREARLEY, HARRY.—The Case-hardening of Steel. 1914.
FURMAN, F. DE R.—Steam Engines and Steam Turbines. 1915.
FURMAN, F. DE R.—Gasoline, Gas, and Oil Engines. 1915.
GOWLAND, WILLIAM.—Metallurgy of the Non-ferrous Metals. 1914.
HINCHLEY, J. W.—Chemical Engineering. Notes on Grinding, Sifting, Separating, and Transporting Solids. 1914.
International Catalogue of Scientific Literature.—Annual Issue, 1912. Chemistry D.
Jahrbuch für Photographie und Reproduktionstechnik. 1914.
JONES, F. D.—Planing and Milling. 1914.
JONES, F. D.—Turning and Boring. 1914.
Moody's Manual of Railroads and Corporation Securities, vol. 2. 1915.
OSTWALD, W.—Scientific Foundations of Analytical Chemistry. 1908.
PARSONS, J. H.—Introduction to the Study of Colour Vision. 1915.
Poor's Manual of Public Utilities, No. 3. 1915.
RHODES, H. J.—Art of Lithography. 1914.
SLOCUM, S. E.—Elements of Hydraulics. 1915.
WARBURG, E.—Physik. 1915.
WATSON, WILLIAM.—Experiments and Observations Tending to Illustrate the Nature and Properties of Electricity. 1746.

GIFTS.

American Institute of Metals, Transactions, vol. viii, 1914. Buffalo, 1915. (From the Institute.)
American Wood Preservers' Association, Annual Reports, 1912, 1913, 1914; Proceedings, 1915. Baltimore, Md., no date. (From the Association.)
American Society for Testing Materials, Membership List and Charter and By-Laws. Philadelphia, 1915. (From the Society.)
Astronomical and Astrophysical Society of America, Publications, vol. ii. Ann Arbor, Mich., 1915. (From the Society.)
Baylor University, Catalogue, 1914–15. Waco, Texas, 1915. (From the University.)
Berger, C. L., & Sons, Standard Instruments of Precision, 1916. Boston, 1915. (From the Company.)
Best William N., The Science of Burning Liquid Fuel. No place, 1913. (From the Author.)
British Association for the Advancement of Science, Report, 1914. London, 1915. (From the Association.)
British Columbia Department of Mines, Annual Report of Minister, 1914. Victoria, 1915. (From the Department.)
Bryn Mawr College, Calendar. Bryn Mawr, Pa., 1914. (From the College.)
Buffalo, Rochester and Pittsburgh Railway Company, Annual Report. New York, 1915. (From the Company.)

Canada Department of Agriculture, Appendix to the Report of the Minister of Agriculture, 1914. Ottawa, 1915. (From the Department.)

Canada Department of Mines, Memoir 74, A List of Canadian Mineral Occurrences; Products and By-Products of Coal. Ottawa, 1915. (From the Department.)

Canadian Pacific Railway Company, Annual Report. Montreal, 1915. (From the Company.)

Central University of Kentucky, Catalogue, 1914–15. Danville, Ky., no date. (From the University.)

Champion Rivet Company, Catalogue of Victor Boiler, Structural and Ship Rivets. Cleveland, no date. (From the Company.)

Cincinnati Water Works Department, Annual Report, 1914. Cincinnati, no date. (From the Department.)

Clark Brothers Company, Catalogue of Saw Mill Machinery. Olean, N. Y., no date. (From the Company.)

Colgate University, Bulletin. Hamilton, N. Y., 1914. (From the University.)

College of William and Mary, Catalogue, 1914–15. Williamsburg, Va., no date. (From the College.)

Colorado School of Mines, Catalogues, 1904–1916. Golden, 1904–1915. (From the School.)

Delaware College, Annual Catalogues, 1914 and 1914–15. Newark, no date. (From the College.)

Detroit Twist Drill Company, Catalogue No. 17 of Twist Drills. Detroit, Mich., no date. (From the Company.)

Electrical Testing Laboratories, Inc., Catalogue describing the work carried on by the Laboratories. New York, no date. (From the Company.)

Engineers' Club of Philadelphia, Directory, 1915. Philadelphia, no date. (From the Club.)

Fondation Teyler, Catalogue de la Bibliotheque, tome iv, 1904–1912. Haarlem, Holland, 1915. (From the Institution.)

General Fireproofing Company, Waterproofing Hand Book. Youngstown, Ohio, 1915. (From the Company.)

George Washington University, Catalogues, 1913, 1914, 1915. Washington, no date. (From the University.)

Hadfield, Sir Robert A., Sound Steel Ingots and Rails. London, 1915. (From the Author.)

Horsburgh and Scott Company, Blue Book on Gearing. Cleveland, Ohio, no date. (From the Company.)

India Meteorological Department, Rainfall of India, 1913. Calcutta, 1914. (From the Department.)

Indian Telegraph Department, Annual Reports, 1909–1914. Simla, 1910–14. (From the Department.)

Jellett, Edwin C., Germantown Gardens and Gardeners. Philadelphia, 1914. (From the Author.)

Lewis Institute, Register, 1912–13. Chicago, 1913. (From the Institute.)

Lincoln Memorial University, Catalogues, 1911–14. Cumberland Gap., Tenn., no date. (From the University.)

Locomobile Company of America, The Locomobile Book and Catalogue of Locomobile Worm Drive Trucks. Bridgeport, Conn., no date. (From the Company.)

Lowell Textile School, Bulletin, 1915–1916. Lowell, Mass., no date. (From the School.)

Manchester Steam Users' Association, Thirty-second Annual Report upon the Working of the Boiler Explosions Act, 1882, June 30, 1913, to June 30, 1914. Manchester, no date. (From the Chief Engineer.)

Montana State School of Mines, Catalogue, 1914–15. Butte, no date. (From the School.)

Morris, I. P. Company, Bulletin No. 3, Hydraulic Turbines. Philadelphia, no date. (From the Company.)

Municipal University of Akron, Catalogues, 1914, 1915. Akron, Ohio, no date. (From the University.)

National Tube Company, Catalogue J. Pittsburgh, Pa., no date. (From the Company.)

Oberlin College, Catalogue, 1914–15. Oberlin, Ohio, 1915. (From the College.)

Ohio Chief Inspector of Mines, Thirty-ninth Annual Report, 1913. Springfield, 1915. (From the Chief Inspector.)

Ohio Geological Survey, Fourth Series, Bulletin 18, Building Stones of Ohio. Columbus, 1915. (From the Survey.)

Ohio University, Catalogues 1914, 1915–16. Athens, 1914, 1915. (From the University.)

Ohio Wesleyan University, Catalogues, 1912, 1913, 1914. Delaware, no date. (From the University.)

Pennsylvania Department of Labor and Industry, Commissioner's Report, 1914. Harrisburg, 1915. (From the State Librarian.)

Pennsylvania State College, Annual Report, 1912. Harrisburg, 1913. (From the State Librarian.)

Philadelphia Bureau of Highways and Street Cleaning, Report, 1914. Philadelphia, no date. (From the Bureau.)

Philadelphia Bureau of Surveys, Annual Report, 1914. Philadelphia, no date. (From the Bureau.)

Philadelphia Department of City Transit, Annual Report, 1914. Philadelphia, no date. (From the Department.)

Pierce, Butler and Pierce Manufacturing Corporation, Pierce Fitters Book. Syracuse, N. Y., no date. (From the Company.)

Porter, H. K. Company, Catalogue of Steam Locomotives. Pittsburgh, Pa., no date. (From the Company.)

Pratt Institute, Catalogue, 1914–15. Brooklyn, N. Y., no date. (From the Institute.)

Princeton University, Catalogue, 1914–15. Princeton, 1914. (From the University.)

Purdue University, Catalogues, 1911–12, 1912–13, 1913–14, 1914–15. Indianapolis, 1912–1915. (From the University.)

Queensland Acting Secretary for Mines, Annual Report, 1914. Brisbane, 1915. (From the Secretary.)

Railway Library and Statistics, 1914. Chicago, 1915. (From Mr. Slason Thompson.)

Rensselaer Polytechnic Institute, Catalogue, 1915, Troy, N. Y., no date. (From the Institute.)

Rumsey and Company, Catalogue of Hand and Power Pumps, 1915. Seneca Falls, N. Y., no date. (From the Company.)

Sellers, William, & Company, Incorporated, Catalogue of Locomotive Injectors and Boiler Attachments, 1915 Edition. Philadelphia, no date. (From the Company.)

Smithsonian Institution, Annual Report, 1914. Washington, 1915. (From the Institution.)

Société des Arts de Genève, Comptes Rendus de l'Exercice, 1914. Geneva, no date. (From the Society.)

Stecher, Charles Company, Catalogue of Automatic Can Making Machinery. Chicago, no date. (From the Company.)

St. Louis University, Catalogue, 1915. St. Louis, no date. (From the University.)

Syracuse University, Bulletin, 1915. Syracuse, N. Y., no date. (From the University.)

Tasmania Department of Mines, Geological Survey Bulletin No. 19. Hobart, 1915. (From the Department.)

Tufts College, Catalogue, 1914–15. Boston, no date. (From the College.)

Tulane University of Louisiana, Registers, 1912–13, 1913–14, 1914–15. New Orleans, La., no date. (From the University.)

Union College, Catalogue, 1914–15. Schenectady, N. Y., no date. (From the College.)

U. S. Department of Education, Report of the Commissioner, parts 1 and 2, 1914. Washington, 1915. (From the Department.)

U. S. Department of State, Diplomatic and Consular Service of the United States, 1915. No place, no date. (From the U. S. Secretary of State.)

U. S. Department of Terrestrial Magnetism, vol. ii, Land Magnetic Observations, 1911–13, and Reports on Special Researches. Washington, 1915. (From the Department.)

University of Arizona, Catalogue, 1914–15. Tucson, 1915. (From the University.)

University of Florida, Catalogues, 1912–13, 1913–14, 1914–15. Gainesville, no date. (From the University.)

University of Iowa, Catalogue, 1914–15. Iowa City, no date. (From the University.)

University of Maine, Catalogues, 1913–14, 1914–15. Orono, 1913–14. (From the University.)

University of Nevada, Catalogues, 1914–1915. Reno, no date. (From the University.)

University of Oklahoma, Catalogue, 1914–15. Norman, 1915. (From the University.)

University of Texas, Catalogue, 1914–15. Austin, no date. (From the University.)

University of Vermont, Catalogue, 1914–15. Burlington, no date. (From the University.)

University of Virginia, Catalogues, 1913–14, 1914–1915. Charlottesville, no date. (From the University.)

University of Wyoming, Catalogues, 1914, 1915. Laramie, no date. (From the University.)

Upper Iowa University, Catalogue, 1914–15. Fayette, no date. (From the Norton Company.)

Verein Deutscher Chemiker, Mitglieder-Verzeichnis für 1915. Leipzig, no date. (From the Verein.)

Waltham City Documents, 1914. Waltham, Mass., 1915. (From Mr. Richard Steele.)

Washburn-Crosby Company, Wheat and Flour Primer. Minneapolis, Minn., no date. (From the Company.)

Wellesley College, Calendar, 1914–15. Wellesley, Mass., 1915. (From the College.)

West Virginia University, Catalogues, 1912–13, 1913–14, 1914–15. Morgantown, no date. (From the University.)

Wisconsin Historical Society, Proceedings, 1914. Madison, 1915. (From the Society.)

BOOK NOTICES.

Chemistry of Familiar Things, by Samuel Schmucker Sadtler, S.B. Philadelphia, J. B. Lippincott Company, 1915. 320 pages, illustrations, 12mo. Price, $1.75.

Chemistry is intractable material to the popularizer, and his success with it has been small, compared with that achieved by those who have attempted to make astronomy, for instance, intelligible to the layman. The most conspicuous exception is Lassar-Cohn's "Die Chemie im täglichen Leben," which, for reasons not altogether clear to the reviewer, has gone through seven editions and has been translated into thirteen languages.

Professor Sadtler is to be congratulated on the manner in which he has carried out his difficult task. There are few errors. The style is usually dignified and straightforward, and there is a refreshing absence of that tedious semi-jocular vein which the magazine "scientist" appears to consider an inevitable part of his output.

Such criticisms as the reviewer has to offer are largely matters of taste and opinion. The treatment of the period law (pages 28, 29, and 30) would convey nothing to the layman. It is somewhat unfortunate that the Brin oxygen process (page 109) is described as still in use. Lime is hardly a part of the burden of the ordinary iron blast-furnace (page 116). Drying the blast (page 116) is still the exception, though it may become the rule. It is carbon monoxide, not carbon, which reduces the iron oxide (page 116). The statement (page 116) that the object of the Bessemer process, as worked in the United States, is "to oxidize the silicon and carbon so that they can be removed by lime" will not meet with the approval of the metallurgist. Few chemists will be willing to attach so much importance to Ramsay's results on the "degradation" of copper, thorium, etc. These, however, are minor points. Professor Sadtler is always interesting and usually accurate, and his book deserves to be widely read.

ROBERT H. BRADBURY.

CHEMICAL GERMAN, by Francis C. Phillips. Second edition. Easton, The Chemical Publishing Company, 1915. 252 pages, 8vo. Price, $2.

The first edition of this excellent book was reviewed at some length in this JOURNAL.* The fact that a second edition has appeared so soon after the first is an indication that the book has filled a gap which, in fact, has been noticed by teachers for many years. There seem to be few changes, and sweeping changes were unnecessary, for, being specifically a reader for Chemical German, the book does not grow antiquated with the same speed as an ordinary text. The student who works through Professor Phillips's book faithfully may attack the German chemical literature with confidence. He will find no insuperable difficulties.

ROBERT H. BRADBURY.

BRIEF COURSE IN METALLURGICAL ANALYSIS, by Henry Ziegel. Easton, The Chemical Publishing Company, 1915. 72 pages, quarto. Price, $1.

This is a text-book "written for the use of upper classmen, trained in elementary qualitative and quantitative analysis." The chief characteristic is brevity: there are sixty-six pages; thirty-three are blank, apparently intended for recording students' analyses. There is no index, but the table of contents suffices.

Ordinary methods of analyses of iron ores, iron and steel; limestones; slags and clays; non-ferrous alloys, ores, and mattes are given with extreme brevity, often at the expense of completeness. For example: Under the head of "Silicon in Iron and Steel" four brief paragraphs cover the entire subject, and it is merely stated that "Ferro-silicons require fusion with Na_2CO_3 and Na_2O_2, preferably in a nickel crucible."

Five paragraphs are devoted to determination of Carbon and three to Titanium, and the analyses of other elements are correspondingly briefly disposed of.

The book may be useful as a "tickler" for upper classmen, but will not supplant more complete text-books.

A. E. OUTERBRIDGE, JR.

---

* December, 1913, issue.

A COMPEND OF MEDICAL CHEMISTRY, INORGANIC AND ORGANIC, INCLUDING URINARY ANALYSIS, by Henry Leffmann, A.M., M.D., Professor of Chemistry in the Woman's Medical College of Pennsylvania and in the Wagner Free Institute of Science. Blakiston's Quiz Compends, sixth edition, revised. 241 pages, 12mo. Philadelphia, P. Blakiston's Son & Co.

The sixth edition of the work has been thoroughly revised and contains the latest information on medical and clinical chemistry, arranged to meet the needs of students in the medical and dental colleges. Since the appearance of the first edition the number of pages has been doubled—an indication of the expansion of chemistry and the popularity of the book among students of medicine.

PUBLICATIONS RECEIVED.

Text-books on Chemical Research and Engineering, Surface Tension and Surface Energy and their Influence on Chemical Phenomena, by R. S. Willows, M.A., D.Sc., and E. Hatschek. Reprinted from *The Chemical World.* 80 pages, illustrations, 12mo. Philadelphia, P. Blakiston's Son & Co., 1915. Price, $1.

U. S. Bureau of Mines, Miners' Circular 18, Notes on Miners' Carbide Lamps, by James W. Paul. 10 pages, 8vo. Washington, Government Printing Office, 1915.

On an Investigation of the Accuracy of the Lens and Drop Method of Measuring Refractive Index. R. NETTLETON. (*The Physical Society of London, Proceedings,* vol. xxvii, part v, August 15, 1915.)—If a few drops of liquid be introduced between a plain mirror and a thin convex lens we have in effect a combination of the latter with a plano-concave lens of the liquid. From a knowledge of the curvature of the lower face of the convex lens, together with its focal length and that of the combination, the refractive index of the liquid used can be calculated.

The lens and drop method of comparing refractive indices is a very accurate one when due regard is paid to the choice of lenses and allowance made for the thickness. It is easily adapted to the optical bench and monochromatic light, and measurements may be made very quickly. The method is perhaps seen at its best when employing a suitable converging meniscus to measure refractive indices between 1.3 and 1.4. The method of measuring short radii of curvature in terms of the well-known refractive index of water is also frequently very useful and accurate just when other means are difficult or inaccurate. The lens and drop method may also be of service in finding the refractive index of the material of the lens. The apparatus employed is very suitable as providing a laboratory experiment for advanced students in view of the accuracy of the results obtained by the inexpensive adaptation of standard apparatus.

CURRENT TOPICS

Uses of Chromic Iron Ores. (*United States Geological Survey Press Bulletin No. 233,* September, 1915.)—Chromic iron ores are used for diverse purposes. They are in great demand in making refractory chrome bricks and furnace lining; in making alloys; in manufacturing steel for cutting tools, projectiles, and armor plate; in a great chemical industry which produces many colors and dyes, and in tanning. California produced almost the entire annual output of chromic iron ore reported in the United States in 1914, and a small output of chromite sand was reported from several points near Baltimore, Md., in that year. The opening of the Panama Canal is expected to obviate in large measure the difficulty formerly experienced in supplying California chromite to eastern manufacturers.

A Process for the Rapid Estimation of the Quantity of Metal Deposited in Nickel Plating. M. Pontio. (*Comptes Rendus,* vol. 161, No. 7, August 17, 1915.)—This method in principle depends upon the combined action of hydrogen peroxide and mineral acids in contact with iron and copper. If a plate of metal or other object nickelled by electrolysis be introduced in a cold dilute solution of HCl and 12-volume H_2O_2 of suitable proportions: (1) A more or less rapid penetration of the oxidizing mixture through the interstices of the electrolytic deposit of nickel. The speed of this penetration is a function of the quantity of metal deposited and the proximity of its molecules; and, in the case of a sufficient and uniformly distributed thickness, becomes effective only when the solution has destroyed a part of the nickel to reach the copper underneath. (2) A slow attack in the cold of the nickel which will aid the penetration of the oxidizing mixture to the metal underneath. Three cases may occur in which this action will take place:

(*a*) *When the underlying metal is copper:* If the coating of nickel is thin (less than 1 mg. per sq. cm.), the formation of $CuCl_22H_2O$ will take place at once. If the coating of nickel is sufficient (from 2 mg. to 3 mg. per sq. cm.), the formation of $CuCl_22H_2O$ will be accompanied with $NiCl_26H_2O$, and in this case the formation of these salts, determined by the green color, will be the more rapid as the nickel coating is the thinner, the nickel being only slightly acted upon by the reagent.

(*b*) *When the underlying metal is iron:* In this case the formation of perchloride of iron is much more rapid than that of the cupric chloride for an equal quantity of nickel.

(*c*) *When the underlying metal is iron, but is coated with copper before being nickelled:* If the layer of nickel is thin, the copper will appear immediately, followed closely by the appearance of the iron. If the nickel coating is heavy, only the iron will appear at the beginning of the reaction, followed by the appearance of copper after a time, which will be proportional to the quantity of nickel deposited.

In these three cases, then, the appearance of salts of iron and copper determines the end of the reaction, observable by the final formation of the double salt (for copper and nickel), and aided by a cautious addition to the mixture of a requisite quantity of concentrated ammonia.

Battery Zincs: Some Causes of Defective Service. R. JOB and F. F. WHITE. (*American Society for Testing Materials, Proceedings,* June 22–26, 1915.)—The serviceability of the zinc element of a gravity cell, such as is commonly used in railway service, is generally considered to depend mainly upon its composition, and it is specified usually that the percentage of iron shall be a minimum of about 0.10 per cent., lead not to exceed 0.50 per cent., and not less than 2 per cent. of mercury.

Of two lots having the requisite chemical composition, one proved altogether unsatisfactory in service. The cause was disclosed by etching and microscopic examination. The satisfactory sample proved to be of fine grain and of uniform structure clear to the outside surface, while the defective sample was of coarse grain, indicating pouring into moulds of a high temperature. The natural inference that the outside metal contained little mercury was verified by the analysis of borings near the surface, the satisfactory sample showing 2.49 per cent. and the defective sample 0.64 per cent.

It is a well-known fact that mercury volatilizes to a considerable extent when added to molten zinc, unless suitable precautions are taken; consequently it is necessary to avoid not only overheating the bath of metal, but also to keep the moulds cooled. Evidently in the case of the defective zincs this latter practice had not been followed, hence the proportion of mercury upon the surface of the zincs was extremely low and insufficient to protect the zincs from local action.

Effect of Transient Voltages in Dielectrics. F. W. PEEK, JR. (*Proceedings of the American Institute of Electrical Engineers,* vol. xxxiv, No. 8, August, 1915.)—In practice, failures of dielectrics are generally caused by transient voltages. It is therefore of great practical importance to determine the various phenomena affecting the strength of dielectrics and means of protecting them when they are subjected to known transient voltages. An impulse generator from which impulse voltages of any given wave-front, length of tail, etc., can be obtained, is described.

Energy is required to rupture gaseous, liquid, and solid dielectrics: this introduces a time element. Thus, on account of this time lag, when voltage is applied at a very rapid rate, as by impulse, spark-over does not occur when the continuously-applied breakdown voltage is reached. The voltage "overshoots" or rises above this value during the time rupture is taking place. This excess or rise in voltage above the continuously-applied breakdown value is greater the greater the rate of application. The time depends upon the nature of the dielectric, the dielectric field, the shape and spacing of the electrodes, initial ionization, etc.

The strength of air between spheres and needles for impulses of different front, length of tail, etc., is given, as well as the time in micro-seconds and the voltage required to rupture air between spheres and needles, on the front of waves rising at various rates.

Transient spark-over and corona voltages for wires, surface spark-over, effects of solarity, air density, practical application, etc., are given.

Transient spark-over voltage and time are recorded for oil and various solid dielectrics.

The general laws of breakdown of dielectrics by transient voltages are summarized.

Natural Gas Production in 1914. J. D. NORTHROP. (*United States Geological Survey Press Bulletin*, No. 236, September, 1915.)—Statistics compiled under the supervision of J. D. Northrop, of the United States Geological Survey, show that the quantity of natural gas commercially utilized in the United States in 1914 exceeded that so utilized in any previous year in the history of the natural gas industry. The quantity produced, which amounted to approximately 591,866,733,000 cubic feet, valued at $94,115,524, constitutes a new record of production, exceeding by nearly 10,000,000,000 cubic feet, or almost 2 per cent., the former record, established in 1913.

Increases in output in 1914 over 1913 were credited to New York, Ohio, Oklahoma, Texas, Louisiana, Alabama, Iowa, and California, the State last named alone recording a gain of nearly 7,000,000,000 cubic feet. Other gas-producing States recorded declines in output, the greatest of which, that of Pennsylvania, amounting to slightly more than 10,000,000,000 cubic feet.

The increases in gas production may be attributed to various causes—in New York to the increased drilling activity stimulated by the advancing petroleum market in 1913 and the early part of 1914; in Ohio to local extensions of the productive fields of the gas belt in the central part of the State and to the development of an important gas pool in the vicinity of Cleveland, Cuyahoga County; in Oklahoma to the development of gas reserves in the Cushing field, Creek County, and the Healdton field, Carter County, as well as to a decided expansion of the local casinghead gasoline industry; in Texas to a greater utilization of the gas supplies available in the Petrolia and Mexia fields; in Louisiana to the greater development of the gas reserves in Caddo and De Soto parishes; and in California to increased demands for domestic consumption in Los Angeles and adjacent towns in the southern part of the State, as well as for industrial consumption in the casinghead gasoline industry.

Of the record-breaking production of natural gas credited to 1914 it is estimated that a total of 203,104,358,000 cubic feet, about 34 per cent., was supplied to domestic consumers at an average price of 28.04 cents a thousand cubic feet, and that 388,762,375,000 cubic feet, the remaining 66 per cent., was supplied to industrial consumers at an average price of 9.56 cents a thousand cubic feet. During the last four years the ratio of domestic to industrial consumption has varied but slightly. Formerly, however, a relatively greater proportion of the annual yield was supplied to industrial consumers.

Conduction of Electricity through Metals. J. J. THOMSON. (*The Physical Society of London, Proceedings,* vol. xxvii, part v, August 15, 1915.)—The investigations of Kamerlingh Onnes on the resistance of metals at the temperature of liquid helium have led to results which are of vital importance in the theory of metallic conduction: they have shown, for example, that some metals can exist in a state where their specific resistance is less than one hundred thousand millionth part of that at 0° C. The transition from a state in which the resistance is diminishing normally with the temperature to the one where they possess this super-conductivity takes place abruptly at a definite temperature, and the difference in the electric properties of the metal above and below this temperature is as well marked as the difference in elastic properties when a solid melts or in the magnetic ones when a piece of iron passes through the temperature of recalescence. One of the most remarkable effects discovered by Kamerlingh Onnes is that when a current was started in a small ring of lead at a temperature of about 4° absolute by bringing a magnet close to it, the current, instead of dying away, as it would have done at 0° C., as soon as the magnet was stopped, went on with practically undiminished intensity, its rate of decay being so slow that Kamerlingh Onnes estimated that it would take four days to fall to half its initial value This power of transmitting a current for long periods when no external electromotive force acts on the metal is one that has to be accounted for by any theory of metallic conduction: any such theory must indicate that in certain metals a change in electrical state takes place at a definite temperature; that above this temperature the current dies away almost instantaneously after the electromotive force is removed, while below it the current may persist for days without undergoing any perceptible diminution.

Government Regulation of Water Powers in European Countries. (*United States Geological Survey, Water-Supply Paper 238.*)—One of the most important problems in the political economy of a nation is the control of water power, and the fact that Congress recognizes its importance is shown by the time devoted to the subject by the United States House of Representatives during the latter part of 1914. It is always interesting and usually helpful, in considering the conditions involved in this problem, to find how other countries have dealt with somewhat similar conditions, so that Water-Supply Paper 238—"The Public Utility of Water Powers and their Governmental Regulation"—issued by the United States Geological Survey in 1910, contains much valuable data. This report, prepared by René Tavernier, chief engineer of the Department of Public Works of France, in conjunction with the United States Geological Survey, treats of the manner in which France, Switzerland, and Italy have dealt with the problem of utilizing more satisfactorily the water powers afforded by the streams in those countries. The French regulations take cognizance of two kinds of streams—first, rivers that are navigable neither for vessels nor rafts, over which the French Minister of Agriculture exercises certain police powers and in which the riparian landowners possess certain rights; and, second, streams that are navigable by vessels or rafts, which lie within the public domain and which are administered by the Minister of Public Works. In Switzerland control of watercourses that are navigable for neither ships nor rafts is retained by the cantons and communes; in Italy the waters are public property, concessions for development being issued by the government.

The laws in force in France, Switzerland, and Italy are given in the report, together with a brief discussion of the results of their operation, as well as their defects and the probability of future changes in the laws.

The Improvement of High Boiling Petroleum Oils and the Manufacture of Gasoline as a By-product Therefrom by the Action of Aluminum Chloride. A. M. McAfee. (*Journal of Industrial and Engineering Chemistry,* vol. 7, No. 9, September, 1915.) —In nearly all cases, the conversion of high boiling petroleum oils into lower boiling-point oils has been effected by the process known as cracking; that is, heating to a sufficient temperature to cause the high boiling oils to become unstable and break down into lower boiling oils. Among the many difficulties occurring in the operation of this process is the danger to the operators and the plant incident to the high temperatures and pressures required, along with the deposit of hard coke at the hottest part of the heating element.

In a paper read before the American Institute of Chemical Engineers the author describes the results of tests made at the Gulf Refining Company's plant of the breaking down of high boiling-point oils by the use of aluminum chloride.

In the practical operation of this process, crude petroleum of any kind is first distilled until the naturally occurring gasoline and kerosene is distilled off. In many of our crude oils there is substantially no gasoline present and very little kerosene. But in any event the crude oil is first heated to free it of any moisture it may contain, as the oil must be perfectly dry before adding the aluminum chloride. Anhydrous aluminum chloride is then added to the remaining residual oil and the mixture brought to boiling. The entire distillation extends over a period of 24 to 48 hours at a temperature generally between 500° F. and 550° F. No extra pressure of vacuum or special apparatus is employed; any still provided with a stirrer suffices. Unlike some of the products of cracking, the low-boiling oils produced are sweet smelling, water white, and saturated.

The recovery of the aluminum chloride is an important step in the process and a pointed feature. While the cost of this chemical is lowered when produced on a large scale, it is necessary to recover this reagent to make the process of commercial value.

Emergency Exit from Boiler-rooms. ANON. (*Scientific American,* vol. cxiii, No. 10, September 4, 1915.)—There is no part of a ship's complement that is exposed to such imminent danger in case of disaster as the engine- and boiler-room forces, and particularly the boiler-room under pressure makes it necessary that all means of access to the boiler-room compartments and exit from them shall be closed while forced draft is in use. In the majority of cases the means of exit from a boiler-room consist of openings on the roof, reached by steel ladders which are normally closed by steel covers.

In order to provide an effectively closed stoke-hole system with a ready means of exit in an emergency, Mr. Ernest H. Peabody, of the Babcock & Wilcox Boiler Company, has designed an ingenious and very effective water-seal arrangement at the exit opening through the bulkhead. In the floor of the boiler-room a tank is built about the opening, which is filled with water approximately to the level of the floor. The bulkhead between the fireroom and the escape front is brought down several inches below the surface of the water in the tank, thereby providing an effective water seal to prevent the passage of steam.

In the event of an accident followed by a rush of steam into the boiler-room, the firemen jump into the water, pass under the lower edge of the bulkhead, and so escape.

Molten Zinc as a Reagent for the Microscopic Etching of Iron and Steel. J. L. JONES. (*American Society for Testing Materials,* Annual Meeting, June 22–26, 1915.)—The samples are immersed in molten zinc for varying periods, low-carbon steels requiring a longer time than high-carbon steels. The adherent dross and metallic zinc are removed partly by mechanical means and partly by the aid of dilute sulphuric acid. Defects in steel are thus plainly disclosed, porous areas being attacked to a marked degree, while the non-porous areas are scarcely attacked at all.

High-carbon steels are more readily attacked than low-carbon steels, and lack of uniformity may be thus ascertained, as well as the depth and character of case-hardening.

High-speed steels are etched in a remarkable manner that indicates that the constituent metals are seldom, if ever, perfectly alloyed. The deeply-etched spots are probably very high-carbon areas that are vigorously attacked by the molten zinc.

Steel-reinforced Aluminum Cables. E. T. DRIVER and E. V. PAUNELL. (*Electrical World,* vol. 66, No. 10, September 4, 1915.) —For many years the adoption of aluminum conductors for long-distance transmission lines has been found economical. However, owing to the lower tensile strength of this material, it is impossible to pull up such conductors as tightly as copper. The greater sag on the aluminum cables necessitates higher and more expensive towers, and in some cases the economy resulting from the use of the light metal has been more than counterbalanced by this fact. This has been the main reason for the introduction of the steel-centre aluminum conductors and the fact that such composite cables have been in use for more than ten years indicates that this project is now beyond the experimental stage.

Among a number of important power undertakings using this type of conductor, two alone employ in the aggregate 70,000,000 pounds of steel-aluminum conductors.

The simplest form is that in which six aluminum strands are laid up around a central steel wire, all of the seven strands being of the same size. This is used for the smallest sizes of cable up to about No. 1, A.W.G. (B. & S.). Larger areas, up to about 225,000 circ. mils, usually have the single steel wire replaced by a seven-wire steel cable of the same area. The ratio of steel to aluminum is the same in both cases. Cables larger than 225,000 circ. mils are usually of thirty-seven or sixty-one strands.

At present, under the average market conditions, a transmission system employing aluminum conductors is frequently cheaper than the equivalent line erected with copper, notwithstanding the higher cost of the towers in the former case. If the towers can be reduced in cost, the economic advantages are more than ever on the side of aluminum, particularly as the extra cost involved by the steel core is trifling. Formulas and data are given for the computation of sag and stress for these composite conductors.

Visibility. C. C. PATERSON. (*Illuminating Engineering,* vol. viii, No. 5, May, 1915.)—The discrimination of detail in certain circumstances depends almost entirely either on shadow or on the direction of the incident light. The question has a wide practical application in the manipulation of unicolored fabrics with no natural contrasts. A person doing needlework with such materials depends for the discrimination of the detailed strands of the fabric on the small shadows cast by one strand on the next, and on the varying brightness over the curved surfaces of each individual strand. Both these factors depend on the unidirectional character of the light incident on the material and the inefficiency of thoroughly-diffused (that is, indirect) light, for such work is most marked. The writer has for ten years used indirect lighting for domestic use, and for a long time ridiculed the assertion that was often made that it was a most unsatisfactory light by which to do needlework, particularly darning. After experiment, however, it is clear that the contention is sound, and that there is nothing so good as unidirectional light giving harsh shadows for the discrimination of detail in needlework of all kinds. Indirect lighting, with its soft shadows, is an ideal light for domestic use except in respect to this one particular.

Sandstone Varieties. (*U. S. Geological Survey.*)—The products of rock decomposition may be reconsolidated either by great pressure or by the injection of cementing materials, or by both. Thus sands are formed into sandstones, clays become shales, and calcareous deposits yield limestone. Aside from their cementing materials, sandstones differ in composition exactly as did the sands of which they are composed. Sandstone may be nearly pure quartz, or quartz and feldspar, or quartz, feldspar, and mica, and it may vary in texture from the fine to the coarse. Some sandstone is so coarse that it will hold six quarts of water to the cubic foot, and underground deposits of such sandstone form excellent reservoirs, which may yield a never-failing supply of water. An arkose sandstone from the quicksilver region of California, made up of granitic detritus, was found to contain quartz, orthoclase, oligoclase, biotite, muscovite, hornblende, titanite, rutile, tourmaline, and apatite. In short, all the rock-forming minerals which can in any way survive the destruction or grinding up of a rock may be found in sands, and therefore in sandstones.

An Instrument for the Optical Delineation and Projection of Physical Curves. J. A. FLEMING. (*The Physical Society of London, Proceedings,* vol. xxvii, part iv, June 15, 1915.)—This instrument is designed for projecting on to a screen or photographing on a plate such curves as magnetic hysteresis, resonance or characteristic curves which can be performed slowly or are non-periodic or non-repetitive. It consists of a base-board on which is fixed a thin wooden ring wound over with one layer, in close turns, of insulated Eureka wire. The insulation on the top surface is removed so as to expose the wire. At the centre of the ring there is a pivot which carries a radial arm, the end of which rubs on the base Eureka wire. The ends of the Eureka wire are connected to a battery, and the middle point of the wire is connected to a terminal and also the centre of the radial arm to another terminal. The arrangement forms a circular potentiometer, so that any required fraction of the battery voltage can be produced in either direction between the last-mentioned two terminals. On the same base there is a rectangular mirror slung on a longitudinal axis, which mirror is tilted by a thread wound round the shaft of the radial arm of the potentiometer. Hence if a ray of light from a mirror magnetometer or galvanometer is reflected to a tilting mirror, and thence to another fixed mirror with its axis at right angles to that of the other, and thence to the screen, the spot of light will have two motions,—one a horizontal one proportional to the displacement of the radial arm and therefore to the potentiometer displacement of the two terminals, and another vertical motion proportional to the deflection of the galvanometer or magnetometer. If, then, we place behind the magnetometer a long coil having a long iron wire within it and send a current through this coil which is supplied from the potentiometer travelling terminals, the spot of light will be actuated by two motions,—one a horizontal one proportional to the magnetizing force, and the other a vertical one proportional to the central flux density in the iron. It will therefore describe a hysteresis curve when the radial arm is moved to and fro cyclically through a certain arc or angle. In the same manner the instrument can be used to delineate characteristic curves of wireless detectors or rectifiers or other devices. By using a rotating condenser of variable capacity in place of the circular potentiometer, the instrument can be used for delineating resonance curves of wireless telegraph plants.

Muddiest of Rivers. (*U. S. Geological Survey,* Bulletin 612.)—The Missouri is the muddiest river in the Mississippi Valley; it carries more silt than any other large river in the United States except possibly the Rio Grande and the Colorado. For every square mile of country drained it carries downstream 381 tons of dissolved and suspended matter each year. In other words, the river gathers annually from the country that it drains more than 123,000,000 tons of silt and soluble matter, some of which it distributes over the flood plains below to form productive agricultural lands, but most of which finds its way at last to the Gulf of Mexico.

It is by means of data of this kind that geologists compute the rate at which the lands are being eroded away. It has been shown that the Missouri River is lowering the surface of the land drained by it at the rate of one foot in 6036 years. The surface of the United States as a whole is now being worn down at the rate of one foot in 9120 years. It has been estimated that if this erosive action of the streams of the United States could have been concentrated on the Isthmus of Panama it would have dug in 73 days the canal which has just been completed, after ten years' work, with the most powerful appliances yet devised by man.

A Curious Mineral. (*United States Geological Survey, Press Bulletin No. 235,* September, 1915.)—Perhaps the most curious mineral found in the United States is staurolite, otherwise known as the "fairy stone." This is an iron-aluminum silicate found only in Virginia and North Carolina, the reddish-brown and brownish-black crystals occurring in well-defined single and double crosses. There is some commercial demand for the crosses as curios, which are worn as watch charms or on chains in the manner of a locket or lavaliere—a demand perhaps stimulated by a legend relating to their fairy origin.

The Extraction and Separation of the Radioactive Constituents of Carnotite. H. M. PLUM. (*The Journal of the American Chemical Society,* vol. xxxvii, No. 8, August, 1915.)—Ever since the discovery of radium by Mme. Curie, and the announcement of its wonderful properties, there has been a very great demand for this element. On account of its scientific interest, such extensive investigations have been carried out that the supply of radium has at all times fallen short of the demand. The more recent claim that it has therapeutic value in the treatment of such diseases as cancer has so greatly increased the demand that the study of the radium-producing ores, along with the best methods of extracting the radioactive material, has become extremely important.

In this paper a careful study has been made of a Colorado carnotite and a satisfactory method worked out for the extraction of the radioactive ingredients. Several of the commercial methods now in use for removing vanadium and uranium from a carnotite ore have been examined and modified so as to be effective in treating our ore, which was found not to be a pure carnotite, but a mixture of this mineral with a vanadiferous silicate containing vanadium in a condition difficult to remove. The method finally adopted gives good results. The uranium is removed by boiling the carnotite concentrates with a sodium carbonate solution precipitated as a uranyl sodium carbonate by merely concentrating the filtrate, and the soda is again recovered. The radium, actinium, and radio-lead are contained in the filtrate obtained by boiling the residue insoluble in soda solution with hydrochloric acid. That part of the radium still held in the residue is then removed with boiling nitric acid. The ionium is finally recovered from residue by boiling with sulphuric acid, and is then concentrated with cerium rather than with thorium, from which it cannot be separated by any known reaction.

PRESS OF
J. B. LIPPINCOTT COMPANY
PHILADELPHIA

JOURNAL
OF
THE FRANKLIN INSTITUTE

DEVOTED TO SCIENCE AND THE MECHANIC ARTS

VOL. CLXXX NOVEMBER, 1915 No. 5

THE PRODUCTION OF LIGHT BY ANIMALS.*

BY

ULRIC DAHLGREN, M.S.,
Professor of Biology, Princeton University.

INTRODUCTION.

ORGANIC life, as we understand it, appears to be a product of the latter part of the existence of cosmic bodies. After some unknown beginning as a heated mass, such a body cools until the higher temperatures have fallen far toward the absolute zero, and then a crust is formed by the crystallization of some of the varied elements present, and, among these, certain elements unite to form the bodies of organized beings; of plants and animals.

These plants and animals are to be looked upon, from one narrow point of view, as self-sustaining and self-perpetuating machines that are constantly releasing energy; and they perform this work in spite of the fact that they are also engaged in adding properly proportioned and elaborated masses to their own bodies as well as secreting part of their substance into the form of materials that are to be thrown off and used outside of the body for purposes useful to the organism.

The energy released is also in the forms that are most useful

---

* Based on a paper presented at a meeting of the Section of Physics and Chemistry held Thursday, January 28, 1915.

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

Copyright, 1915, by THE FRANKLIN INSTITUTE.

to the organism. Sometimes it is hidden in chemical changes whose products are to be used at some future time; and in this case a certain portion of the energy, a very small residue, appears as a by-product, consisting of electricity, or heat, or motion; perhaps sometimes even of light.

At other times, however, the energy is produced in an active form and in large quantities, as motion, or heat, or electricity, or light, and is developed in tissues or organs specialized for the purpose and in quantities which in most cases suffice for the performance of duties that are of real use to the life of the organism. Thus, motion is produced in useful amounts, as in the cat, or gull, or squid; heat, as in the bee or bird; electricity, as in the *Gymnotus* or *Torpedo;* and light, as in the fire-fly, or fish, in worms, and other lower forms of life.

The number of organisms which possess the powers of releasing energy in the four forms mentioned above has an interesting relation to the values that the forms of energy possess as factors in the life of the organism. Motion is of such paramount importance in any creature's life, especially if it be an animal, that we find it to be of almost universal occurrence. Even if we fail to consider the physical movements that occur in the cell and its organs, or the motion of growth, we still can hardly name any animal that does not require a considerable output of motion for its continued existence. The organ of motion, the muscle-cell, occurs as a familiar feature in sections of almost any animal body. In smaller kinds the ciliated cell is more abundant, and even in some larger animals the surfaces covered with such cells generate large and strong currents of water or streams of mucus.

Next in importance to motion I should place the generation of heat. It is true, of course, that our present seats of life on the earth's surface are all more or less heated to a point above the absolute zero; usually to a point somewhere from freezing-point up to the neighborhood of 100° F. And, certainly, vast numbers of creatures live normal lives in these temperatures, or even outside of them, without having the power to materially raise their own internal temperature above their surroundings. Still, I think all will acknowledge that most of the best and more interesting forms of life have acquired the power of producing this important form of energy within their bodies so as to keep them at a fixed temperature that is usually much above the surrounding media in which they live. A few insects and nearly half of the large group of vertebrates are about the only animals that have this power. This indicates a rather narrow distribution of heat production in the animal kingdom, but it also shows a distribution among the most important part of this kingdom, as well as among a very large number of species. Further, it is a consistent distribution: where one species of a genus possesses it, so do all the others in nearly every case. It indicates to some degree a phylogenetic relationship.

The most narrow distribution of energy production is found in the case of the power to produce electricity. This seems to be restricted to the fishes alone, although it is always possible that some of the constantly recurring reports of its existence in some invertebrate forms may some time prove to be true. It is confined not only to the fishes, but to only certain groups of them, to certain more or less widely separated genera or families which show no genetic relationship to each other, so far as their electric powers are concerned.

Lastly, we find the power of releasing energy from the body in the form of light. As in the case of electricity production, this power shows an irregular and eccentric distribution. It is a much wider allotment than in the case of electricity, nearly all the larger groups of animals as well as many of the plants showing some single member or several members that can shine in the dark. Still, it remains true that most animals can emit no light, that the largest number depend on other sources than their own bodies for the light by which they see, perform photosynthesis; or which they use as an ornament, a threat, or an attraction to the creatures around them. Were the luminous species counted it would more than probably be found that they constituted less than one per cent. of the known forms of life.

The manner in which human attention is attracted to this light in organisms is a matter of interest. To the natural wonder excited by its rarity is usually added the mystery of darkness and usually the imaginative stimulus of the sea or the country and woods in which most of the light exhibitions take place. Under such circumstances the accounts brought in by the average traveller are exaggerated, and further inaccuracy is assisted by the fact that in observing such an animal by night one sees only the light and cannot observe the creature that produces it except with great difficulty. It takes a certain kind of moral courage to leave a cosey fireside or comfortable cabin and go out in the dark, not only to see the lights, but also to capture the animals that produce them and study the manner of their production in anything like a scientific way.

Thus the production of light, like the production of electricity, is not accepted as a normal fact by most people. It does not enter into their personal lives in the same way that heat and motion do, and when brought to their notice it is regarded as " wonderful " and incomprehensible, although motion is a more complex and more wonderful form of energy production than any one of the other three.

The appearance of light, then, shining out of an animal's flesh and taking its origin in that flesh, is a spectacle that is well calculated to produce wonder. And where wonder comes, curiosity is aroused and questions will be asked. Is the light caused by phosphorus? Why does it not burn the fire-fly? Is it hot? How is it controlled? etc., are but a few of the queries that a thoughtful person will imagine on the spot when a worm, or mollusk, or echinoderm is exhibited glowing or flashing in the dark, and the following series of papers are but a crystallization of the writer's researches and reading in an effort to answer many of these questions.

As a method of presentation it has been deemed possible to treat of the light-producing power by beginning with the plants and lower animal forms and describing the higher groups in turn, using each group as a basis for the explanation of certain of the several principles that appear to govern the processes. Finally, some of these general truths will be made the subject of special chapters in which they can be more fully discussed.

THE BACTERIA.

It seems fitting that some species of that great primitive group of organisms, the bacteria, should be endowed with the light-producing power. Such is the case, and we find some of the most interesting exhibitions of luminosity displayed by these minute organisms. They have served, too, for the demonstration of some of the more important truths concerning light production by investigators in this field. Nowhere else can we find the various physiological functions of life in so simple a condition and so clearly divorced from morphological structure. Certain known features of structure, such as the marked external membrane and other possible but unknown segregations of protoplasmic material, undoubtedly condition the formation of materials and performance of functions, but here, if anywhere, we can feel or even prove that in the same uniform flesh all the different life functions take place and all the substances that bacteria secrete and handle are formed in the same undifferentiated protoplasm.

The bacteria are a group of organisms that are so small in size that we find it hard to classify them on their morphological structures. It is true that they are sometimes labelled and arranged according to their shape, the possession of flagellæ, of a pellicle, etc., but one of the principal and most important factors used in giving them name and place in a system of nomenclature is what they will *do*. In hardly any other living group will it be possible to find a classification so based on the intrinsic physiology of the forms.

One of the earlier attempts to classify the particular forms of bacteria in question was by constituting a group, the photobacteria, thus frankly grouping them according to whether they produced light or not. It seems probable, however, that this property of giving off light must have originated independently in more than one particular group of bacteria, and such independent origin would at once break up the phylogenetic homogeneity of this arrangement.

Gorham, in 1903, studied many of the forms with great care, and, after consulting the literature on the subject, enumerated some twenty forms, with their synonyms, that he considered as well-described and separate species, and five others that appeared to be doubtful as to their descriptions.

He distinguished, among the twenty, two groups which seemed to have many characters in common, and called them the *Bacillus pflugeri* group and the *Microspira luminosa* group, the first containing fifteen and the second five of the twenty forms that he recognized. He also isolated and studied two forms, from sea-water and on mammal-flesh and fish, that belonged one to each group, but did not give these new forms names, saying that they fell in with forms already present in the groups, but not specifying those forms.* The important points in connection with this arrangement are that these two groups do have important structural and physiological differences between them which, if proved by time to be accurate, will divide the photogenic bacteria into two groups of more than generic value. To sum up Gorham's studies, I will quote from him: "It will be noticed that all photogenic bacteria agree in certain particulars. They are all motile under certain conditions, all are provided with one or more terminal flagellæ, none stains by Gram's method, none of them forms spores, none of them ferments sugars according to the method of the Bacteriological Committee. This latter, however, is due to the fact that they are all unable to grow, except very slightly, in solutions containing 1 per cent. of sugar.

---

* Gorham's tables will appear with part two of this article in the December issue of the JOURNAL.

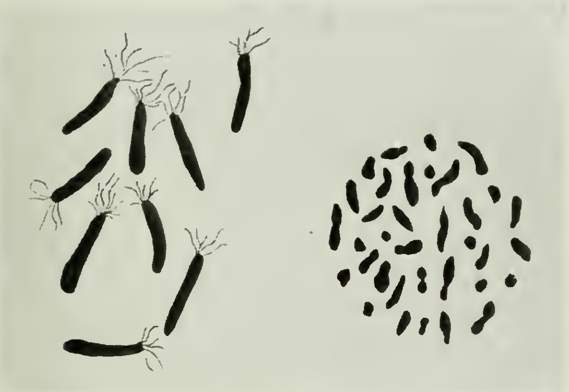
"The characteristics of the two groups into which the photogenic bacteria have been divided may be defined as follows: To the *Bacillus pflugeri* group belong those species of larger size and extremely variable form that do not liquefy gelatine at all, or at least but very slowly, and that grow best at a temperature lower than 22° C.; the members of the second group, the *Microspira luminosa* group, are all of small size, liquefy gelatine, and prefer a higher temperature for growth and luminescence."

More recently (1907) Molisch has made extensive studies on the light-producing bacteria and arranged them under five generic groups: *Micrococcus, Bacterium, Bacillus, Pseudomonas,* and *Microspira.* To these may be added two forms, *Diplobacterium* and *Vibrio,* more recently described by other authors as containing luminous members. These two latter names do not agree with some of the best modern classifications of bacteria according to Migula.

In form most of the luminous bacteria are more or less elongate, although a few are oval or even round (see Fig. 1). Under dark stage illumination they can be seen as rod-shaped organisms in rapid motion with a quick twisting movement such as is used by mosquito larvæ in moving about. This motion is performed by means of the flagellæ with which they are provided and which carry them on a variable, wandering course with great quickness.

Turning to a systematic classification of the known forms of bacteria as formulated by Migula and as slightly modified by Frost and McCampbell, we find that the seven genera mentioned above do come from different families, although most of them are contained in one more or less compact group. It is to be noted that all come from a single order, the *Eubacteria.* Thus they contain no sulphur, and in other ways show a lack of certain characters that mark them as a more primitive type, the sub-order *Haplobacteria,* a division designated as the lower bacteria. In this sub-order we find three families, all of which contain some of our luminous forms. The *Coccaceæ* (first family) shows five genera, only one of which has a luminous member, the genus *Micrococcus.* In the second family, the *Bacteriaceæ,* we find three genera, all of which have one or more luminous species among their number. And, lastly, the third family, the *Spirillaceæ,* shows four genera, two of which have luminous members among their genera.

FIG. 1.



Two groups of luminous bacteria as seen fixed and stained on the slide under the highest powers of the microscope. The left-hand forms are some species of the *Bacillus pflugeri* group, and are stained to show the flagellæ. Those to the right are another member of this group stained without showing the flagellæ.

There remains in this order of the *Eubacteria* another entire sub-order, the *Trichobacteria* (higher bacteria), containing four genera, in which no species are reported as producing light; also the entire other order of bacteria, the *Thiobacteria* or sulphur bacteria, containing two families, six sub-families, and far more genera and species than the first order, in which no luminous forms have ever been described.

All these kinds have been classified on the basis of form, chemical constitution, and, more largely, on multiple physiological characteristics, which, taken all together, form a far stronger basis of classification than the one characteristic of light production. It thus becomes very apparent that luminosity is not a sound basis for the grouping of our light-producing forms, although this power has appeared in a scattered form among those bacteria that are contained in and grouped about the order *Bacteriaceæ*. Thus we must discard the term Photobacteria as applied to a taxonomic group and use it only as a term of convenience in speaking of those various and somewhat scattered forms that can produce light.

The above facts also show that we still need extensive and careful work on the luminous bacteria—work that will serve to identify the different kinds both by peculiarities of their luminous power, as well as by their numerous other reactions, and such characteristics of form and structure as can be discerned under the microscope.

The luminous bacteria do not always glow. For the greater part of their lives they are non-luminous, like other bacteria. They occur in all seas, mostly near or on the bottom or on the beaches, while some are carried inland in various ways and become colonized in marshes, slaughter-houses, or kitchens and in other habitations of man. It is possible that one or more species have become separated from the main group of salt-water forms and become definitely placed as inland species. *Bacillus phosphorens* seems to be such a form. They live and propagate in the small amounts of organic matter in which they are in contact, and, as has been said, they do not produce any light at all under these circumstances of ordinary existence. Many forms are always found living in the slime of the various fishes, mollusks and other creatures of their region.

The natural conditions under which these organisms become luminous have been observed from great antiquity, although the earliest observers did not understand exactly what the significance of the light was. Nor are we sure, from their descriptions, whether they saw a light that was produced by bacteria or by some fungous forms. It was certainly one or the other, however, and we can be fairly sure that in some cases it was a bacterial light.

Already in the days of the Attic intellectual period Aristotle had observed the luminosity of the flesh of dead fish and of domestic animals, and this observation has been repeated from time to time in many ancient writings. Such articles written up to the last century did not mention the fact that this light emanates from living organism or living tissues. On the contrary, the writers seemed always to believe that it was the result of some form of chemical change due to decay, and various theories were set forth to explain it on that basis. In 1676 Boyle made many observations on the physical and chemical conditions under which the light would exist or would disappear, and some of these were facts which are of real importance at the present time in our studies of the power in various animals. For instance, he showed that air was required to maintain the light, and that when thinned or removed by an air-pump the light ceased, only to be restored when the air was replaced. Among other observers of this period were Paullinus in 1707, Martin in 1761, Hulme in 1801, and Davy in 1810. This latter writer attacked the question in a really scientific manner and investigated the effects of many substances upon the light. Hulme and Dessaugnes independently gave formulæ by which the light could be produced from dead fish mixed with certain chemicals and common substances. The idea that this light is a part of the process of decay still persists in the popular mind to-day, and is undoubtedly a relic of the ideas of these earlier investigators and writers.

At last it began to be suspected that the luminosity was part of the activity of living organisms, and Michaelis, in 1830, expressed a suspicion of this truth. He was followed in 1834 by Ehrenberg, and then in 1854 the physiological chemist Heller advanced the opinion that the light of decaying flesh emanated from some form of low plant, to which he gave the name *Sarcina noctiluca*. In 1875 Pflüger independently came to the conclusion that the light from dead fish was caused by microörganisms, and he experimented to prove that. Collecting some of the luminous slime, he diluted it with sea-water and filtered it. The filtrate was without light, while the residue was still luminous. This proved that the luminous material was not a liquid in this case. He also showed that new preparations of nutrient media could be infected with tiny amounts of the luminous substance, thus bringing fairly good proof that the light did come from living organisms of microscopic size.

From this time on many new and well-trained workers entered the field. Armed with the essential facts discovered by the men mentioned above, they applied all the methods used by bacteriologists as fast as discovered, these methods differing from the ordinary biological methods in that they dealt for the most part with large masses of individuals, none of which can be submitted to separate study by any satisfactory means beyond observing its shape and motions.

Among the many scientists who have thus studied the luminous bacteria are Nuesch, F. Ludwig, Dubois, Molisch, Beijerinck, Gorham, Migula, Fischer, Lode, Weleminsky, Reitz, Kutscher, Barnard, Percy-Laurent, Driessen, Ehrenberg, Smith, Giard-Billet, E. N. Harvey, and many others.

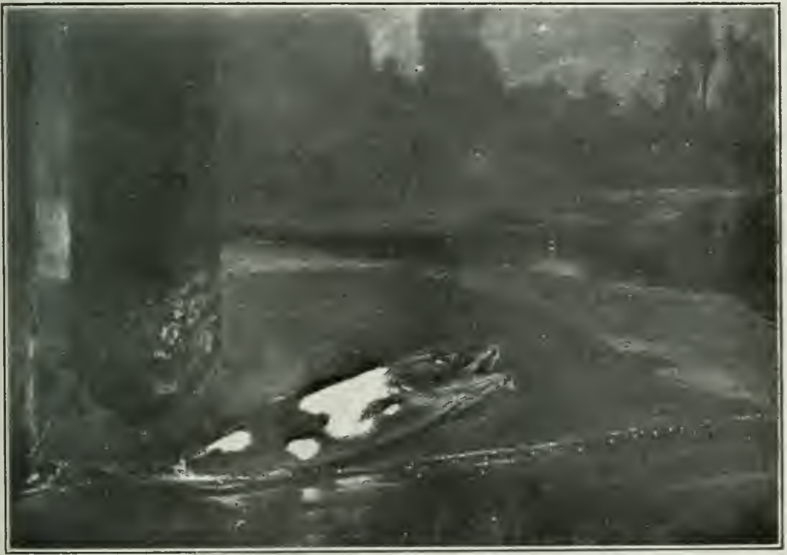
As a result of the work of the above men we have a fairly good idea of the conditions under which these bacteria will show light. These conditions will be considered presently under the headings of "Oxygen," "Nutrient Media," "Salt" (sodium chloride), "Temperature," etc.

The usual natural conditions under which the luminosity of bacteria are seen are as follows: First, it is often seen on the bodies of fish, mollusks, worms, and other sea animals that have been cast upon the rocks or on beaches and in which decay has begun some short time before. The body must be in some sheltered place where there is some moisture and where the temperature is about that of the sea in that neighborhood. A partial covering of moss or grass assists in preventing drying (which inhibits the bacterial growth) and sun-heating (also unfavorable) between the tides during the day.

On almost any sea-beach one can turn over masses of sea-plants that have been washed ashore near high-water mark, and small bits of glowing matter will be seen among the moist middle and lower layers. Such particles consist most commonly of the bodies or parts of small crustacea and other sea forms that have become infected with the bacteria. The pale greenish light glows steadily and does not waver or go out. It will last for some hours or days if the temperature and moisture are maintained and if an abundant supply of fresh air is supplied.

Or, again, a large fish may lie under a fishing dock, half in the water and in the earliest stages of decomposition (see Fig. 2). On its sides will be seen spots and patches of the same greenish light, and by daylight it can be noticed that those areas which shone in the dark are now covered with a thin but distinct coating of semi-transparent slime. Such patches of light will almost cover the body sometimes, and they disappear as the process of decay advances. They are never seen when the body becomes really putrid, and they last usually for from two to five days. Any fresh water touching them will quench the light at once, as will also drying, too much heat, or destructive or poisonous chemicals. The light begins with a faint glow, rising to its maximum slowly, and then disappearing quite suddenly as the latter stages of decomposition set in. In this event, of course, many other bacteria, the commoner forms that cause the processes we call decomposition, have multiplied in large numbers, and, besides consuming the substances that the luminous forms live and shine on, have cast off many products of their activity that are poisonous to the light-producing forms and that inhibit their luminosity. Among such are many organic acids that acidify the media, and we will see that in an acid medium no light is ever produced.

FIG. 2.



Dead codfish lying on the beach under a dock at South Harpswell, Maine. Colonies of luminous bacteria growing on its sides form patches of light when the fish is observed after dark. (Drawing by Bruce Hornfall.)

In few instances does a luminosity appear on bodies that are totally submerged. While it is possible that the bacteria could shine in such a position, for instance, in under-water crannies in the rock or in quiet pools, still the fact has not been observed and published. Also I think it may be stated as a truth that the luminous bacteria of northern seas, while present in most parts of these seas, are never responsible for the general luminosity that we sometimes see in the crests of waves, or on the surf-beaten beaches, or in the wake of a steamer; for it must be remembered always that the bacterial light is a steady one and shines, when it does shine, continuously. It cannot be stimulated by a sudden mechanical shock, or even by electric shock or by heat, from quiescence into activity, as many other forms can.

Gorham reports that in southern seas the bacteria sometimes do cause a general diffused light in parts of the ocean. That a diffusion of bacteria through the sea, while in their proper physiological state for shining, would produce a marked light can be easily seen by mixing an artificial culture of some form like *Bacillus phosphorens* in a large quantity of sea-water. Here we see a glowing fluid with streaks and scums of greater intensity, where the air, owing to movements of fishes or currents, has brought more oxygen in contact with the organisms.

This has been done on the largest scale in the Berlin aquarium, where small quantities of the cultures served to keep the water in large tanks in a state of luminosity for considerable periods. The writer has also used such cultures, mixed with several gallons of sea-water, to illustrate the light-giving power during lectures and demonstrations. Two-tenths of a gramme of centrifuged bacteria in two quarts of sea-water caused a light that enabled one to see faces and read printing at a distance of several feet.

It is doubtful, however, if bacteria ever illuminate large areas of the sea, as do other forms, for any length of time. The principal difficulty would be in finding proper food conditions and in keeping their positions, etc. Nor is it probable that the bacteria illuminate the bottom of the sea at great depths. They probably exist there in the non-luminous condition. They can survive an artificially applied water pressure of over two hundred atmospheres, and it can easily be imagined that they would become accustomed to the abyssal pressure conditions of the ocean deeps. Various proofs exist that these depths are illuminated with a weak light. Creatures with undoubted light-organs assure us that there is some light there. The possession of large eyes fitted for perceiving a very weak light in many deep-sea fishes and crustaceans also points to its more or less universal presence, and, lastly, the use of photographic plates has shown it to be present at considerable depths. Still it is very questionable if the bacteria ever show it decidedly in these positions.

The seat of luminous activity of some of the forms of light bacteria is sometimes found in the flesh of domestic animals and other land creatures that have been slaughtered or even prepared for food, as in the form of sausages. These cases have entered prominently into the life of men and groups of men in a way that the previously-mentioned cases have not. Thus we have records involving these cases in legal and religious affairs, as well as in commercial transactions and household affairs. Butchers have lost their trade or even been haled before a court because strings of luminous sausages or luminous cuts of meat have been seen in their shops at night by neighbors or customers. While the writer is in some doubt as to whether this light was always due to bacteria rather than to some fungous form, still we have good authority (Molisch, Heller, Ludwig and Kohlmann, Gorham, etc.) that, in a number of cases at least, the light was due to *Bacterium phosphoreus*. In all of these cases it is always true that a considerable quantity of salt had been used in preparing the meat for use, and it is probable that the salt was derived from marine sources and was infected with dormant photogenic bacteria from the sea.

Some few of the luminous bacteria are capable of existing on or in living tissues, or they may even be pathogenic and cause disease. Numerous cases have been reported in which the urine of animals and men has been seen to shine as emitted from the bladder or after being allowed to stand for a short time after. Several species of skunks or polecats (*Viverra mephitis* and *Mephitis lybica*) have been reported in this wise, but there is some question as to whether the light was bacterial or was emitted from the mycelium of a fungus. Also it was possible that bacteria or fungous forms came in contact with the urine after it had been emitted.

So also has human sweat been seen to shine. Many cases have been reported; in particular, an Italian woman was reported by Bartholin, and a Bavarian peasant by Hermbstädt, to be luminous when they perspired freely. In the latter case the luminosity was accompanied by a peculiar smell. The odor was very pronounced in a case reported by Henkel, where it resembled old sauer-kraut. In this case the light was seen best on the shirt freshly drawn from the body, and in daylight it was noticed that the shirt showed numerous and very fine red particles on its surface. Panceri has also reported cases of children in which the skin showed luminosity, especially on spots that had been scratched. In all cases it is probable that light bacteria had found a sufficient medium for growth in the accumulated sweat and filth on the skin, sufficient salt being present in the material to provide conditions under which luminosity could be displayed.

The luminous bacteria sometimes enter into a closer association with living animals. In man they may infect and grow in a wound so that it glows strongly in the dark. Such an infection is not pathogenic, however, and it is said by the military surgeons that such wounds heal better than the others. This statement can be believed when we consider that the luminous bacteria probably occupy space and use nutrient materials that they thus deprive other and possibly pathogenic forms of. Tarcgabiff injected a culture of luminous bacteria into the lymph-sac of a frog, and the infection (perhaps only the original bacteria) spread through many of the creature's tissues. They maintained the luminous state in the tissues for some time, light being seen to glow in the tongue in particular for from three to four days. The animal's health did not seem to suffer, and the bacteria were probably all disposed of eventually by the white blood-cells. Similar experiments would seem to be impossible with the higher vertebrates, as the luminous bacteria will not thrive in such high temperatures.

Some insects and small crustacea are known to become luminous at times owing to the presence of light-producing bacteria in their bodies. In certain of these cases the condition does not result in discomfort or disease to the host. Thus in an expedition to Persia and at other times in Russia and neighboring countries it was observed in swarms of gnats (*Chironomus*) that certain individuals were strongly luminous, while the rest showed no light at all. Owing to their short natural life and delicate structure it was not possible to determine whether this was the harmless presence of the photogenic bacteria in the animal's intestinal canal or if it was a pathological condition. Since the luminous animals seemed to be flying in precisely the same way as the rest of their companions, it was concluded that it was not a case of disease. These facts have been described by Alenizyn, Brischke, Osten-Sacken, Henneberg, Kusnezoff, Schmidt, and others.

On the other hand, observers have noticed that certain crustaceans were often liable to infection by a luminous bacterium that resulted in disease and speedy death. Giard and Billet, De Giaza, Russell, Irwin Smith, and Gorham have made studies of this subject. The original researches of Giard and of Giard and Billet are perhaps the most interesting in this regard. They first observed that many individuals of a species of *Talitrus*, an amphipod crustacean, were infected in this manner and shone in the dark; also, that such individuals died in a few days. Cultures and fresh tissue examinations showed the presence of a microörganism or diplo-bacterium which they were able to isolate and keep in sea-water for several days, as well as breed in bouillon media containing the proper amount of sodium chloride. Further, they were able to infect normal *Talitrus* with these bacteria, either from the blood of diseased animals or from the cultures. The infection was performed by cutting off a bit of antenna of the animal to be experimented upon and then applying the diseased tissues to the wounded surface or applying a drop of culture in the same way. The wound healed, but in a period of time between three and four days long the animal began to glow throughout its body, and the light increased slowly, until at the end of four or five days it glowed at its brightest. From this point on the animal showed signs of failing in health and rapidly sickened and died. The failing light continued to glow for some hours after death.

A notable feature of the bacteria was that they would live and multiply in beef and agar media that supported other photo-bacteria in the glowing state, but they would not develop light under those conditions. It was only when living in the blood of the *Talitrus* that they seemed to be able to produce light.

The investigators then tried the experiment of infecting other crustacea with the bacteria and found that nearly allied forms, such as *Orchestia*, *Hyale*, *Ligia*, as well as the isopods *Philoscia* and *Porcellio*, could also be infected. In *Orchestia*, for instance, the light took longer to appear—at least seven days. A wounded crab (*Carcinus mænas*) was also inoculated, and, while the infection did not become general, the wound became luminous and remained so for ten days.

While the luminous bacteria cannot infect a warm-blooded mammal and cause a disease, they can cause its death in a short time by being injected in sufficient numbers. In this case they probably act as a poisonous material, and the luminosity does not appear to have any influence in the result. Tarchanoff reports the infection of mice and guinea-pigs with *Microspira caraibica* and the resulting death of the animals, but it appears doubtful if these cases were other than a poisoning of the creatures by large numbers of the bacteria being injected at one time. Nor did the animals glow from the presence of the bacteria.

It was discovered at an early date that the photogenic bacteria could be artificially grown and managed much as many other forms can in the laboratory. The early investigators, knowing that the growths usually appeared on fishes, and only on the marine forms, elaborated complicated nutrient media in which the flesh of fishes played a prominent part. Beijerinck, Dubois, and Molisch recommended such formulæ as, for instance, Beijerinck's mixture of sea-water containing 8 per cent. gelatin, 0.5 per cent. asparagin, 1 per cent. glycerine, and 1 per cent. peptone. Other formulæ were still more complicated, as Lode's two mixtures, which, while they did contain the essentials of sodium chloride and a nutrient material and were made faintly alkaline, still were far too cumbersome and unnecessarily exact in details of preparation.

Harvey, using the luminous bacteria from smelt and butterfish, as well as a *pseudomonas*, found that a simple medium of beef peptone, 1 per cent., and glycerine, 1 per cent., mixed in sea-water and made faintly alkaline by a trace of potassium hydroxide, served as an excellent medium for raising large numbers of the microörganism in a vigorously luminous state. Also, by using this same mixture, to which enough agar was added to render it firm, he was able to plate the organisms to secure pure cultures and to make stab cultures in test-tubes.

The fluid cultures produced the bacteria in largest numbers, and an examination of the organisms with dark-stage illumination showed them to be in active motion, undoubtedly by means of their cilia, which could not, however, be seen in such preparations. These cultures were raised in a common refrigerator and were pure cultures secured by plating. A very thin layer of fluid was best because of the large requirement of oxygen, and the organisms grew best on the shallowest edges.

Here the light began to show at the end of 24 hours, and attained its maximum in about two days. After a few days more the light began to wane, until finally it ceased, although the living bacteria were still present.

This disappearance of the light was coincident with the appearance of an acid condition of the medium, due, no doubt, to the presence of acid products of the activity of the organisms. In some cases an infection of the culture with other common forms of bacteria resulted in a much quicker failure of the light, showing that the presence of bacterial activity other than that of light production would inhibit luminosity. In many cases the presence of numerous other bacteria finally resulted in the death of the light-giving forms and their complete elimination from the culture. This is the result in nature when a bit of brightly-shining fish flesh is confined in a closely-stoppered bottle for any length of time.

The luminous bacteria can be centrifuged out of the fluid medium mentioned above and collected in a moist, opaque, yellowish-white, sticky mass, and then kept for a much longer time in a brilliant condition by being shaken up and distributed through some quantity of pure sea-water. If the right quantity of sea-water is used, the bacteria will remain glowing for a number of days, especially if a small amount of the fresh medium is also dissolved in it. Or they can be transferred to a quantity of the fresh medium in shallow plates and allowed to multiply until the acidity of the medium again begins to check their luminosity.

Thus, for purposes of study, a given weight of bacteria can be centrifuged out of a fluid medium and distributed through a given amount of sea-water in a vessel of known shape. At a determined stage of development of the light-producing power and temperature such preparations are the best for studies of the properties of their light.

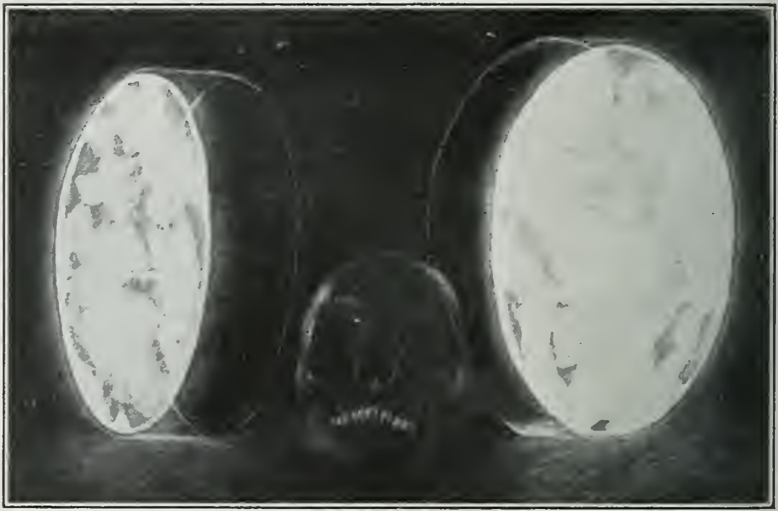
On the surface of the solid form of the medium, as well as on other solid foods, including the surface of dead fish or bits of fish flesh or other dead organisms, the bacteria go through the same process of an increase in numbers and light-producing power and a decline, due to the increasing acid or poisonous properties of their surroundings. Also, here they cannot so easily be collected and handled.

Another method of handling the organism for light investigation is to centrifuge the bacteria out of the food medium and spread a given weight out over a known surface of filter paper or other solid surface. This method permits of certain experiments not possible with the sea-water method.

Some of the first experimenters used a culture growing on a firm gelatin or agar medium surface for their work (see Fig. 3). This method has great drawbacks, in that the growths of the colonies are progressive and the resulting unevenness does not furnish a good source of light.

The bacteria consume free oxygen in the sea-water very rapidly. Thus if ½ gramme of bacteria is centrifuged out of the nutrient medium and distributed in 100 c.c. of fresh, pure sea-water in a 200 c.c. glass-stoppered bottle, they will shine brilliantly for a few minutes and then all become non-luminous, except a thin film on the upper surface. If now the bottle is shaken several times, the entire mass illuminates again, but again becomes dark when allowed to rest. This indicates that the bacteria are so numerous that they exhaust the free oxygen by their light-producing work and resume it again when more oxygen is supplied.

FIG. 3.



Artificial cultures of luminous bacteria in glass dishes photographed in the dark room. The light from these serves to weakly illuminate a skull, which also shows on the plate. (Copied from Molisch.)

But if the ½ gramme of solid living bacteria be distributed in 2000 c.c. of fresh sea-water, they will be so placed that each individual has a sufficient portion of water to furnish free oxygen for several hours, and the mixture will remain glowing for that time.

A very beautiful experiment was performed by Beijerinck, who made a mixture of luminous bacteria and some chlorophyll-bearing algæ and covered the mixture so that no air had any contact with it. After standing a short time in a dark room the light from the bacteria ceased, from lack of oxygen, they having taken the supply of free oxygen out of the water. Then light was admitted to the experiment for a few minutes, and when removed again into the dark the bacteria were once more shining. The cause of their renewed activity in this case was the fact that the light had made possible a photosynthesis by the chlorophyll of the algæ thus liberating oxygen that could be used by the bacteria for light production. Repetitions of the experiment under varying conditions showed that a visible light could be produced for a few seconds by so small an amount of light as the lighting and burning of a single parlor match.

Lode is a scientist with sufficient training in the physics of light to undertake more exact physical measurements of the amount of light emitted by these organisms. He used two forms, *Vibrio rumple* and *Vibrio elvers*, and employed the method of Bunsen to measure the light.

He infected some Petri dishes, small, round, flat, glass dishes, with covers, filled with 20 c.c. of a nutrient agar solution. The dishes were of a size that made a rather thin, wide layer of the agar.

The dishes were then put in an incubator, kept at a proper temperature to allow the bacteria to grow, first in small colonies and later in larger colonies that spread out in patches over the surface of the agar. Selected portions of these colonies were then cut off by a screen with a round hole in it of a given size, and carefully compared with the surface of an opaque, milk-white glass behind which an electric light could be moved backward and forward until its intensity corresponded with that of the bacterial surface.

Comparisons were then made with a German normal paraffin candle, and this was further tested by a Weber photometer.

The results are tabulated on the next page.

Experiment four was selected by Lode as typical of what bacteria can do in producing light, and set forth as follows:

Vibrio rumple.—Intensity per square millimetre—0.000,000,000,785 Hefner candles, which is equal to 0.785 Hefner candle per 1000 square metres, or 0.562 time a German normal candle.

This does not seem to be a very great amount of light, and it is not. Still, the character of the light is such that it acts with a maximum effect on the human retina, as well as, probably, on other eyes in the various animal groups. The light of bacteria has been investigated by several competent men, and the position of its wave in the spectrum (*i.e.*, their length) has been determined with the most delicate apparatus. Ludwig, 1884; Hericourt, 1890; Dubois, 1898; Tarchanoff, 1901; Barnard, 1902; Gorham, 1903; Molisch, Forster, Engelmann, Barnard, and MacFadyen are prominent among the many who have studied this light of bacteria.

EXPERIMENT.

	Bacteria used, nutrient medium, time of development, and temperature.	Diameter of bacterial surface used.	Light intensity measured in German normal candles.	Actual light intensity of 1 square millimetre of bacterial surface.
1	*Vibrio elvers;* beef peptone agar; 24 hours; 37° C.	0.9 centimetre	0.000,000,056,5	0.000,000,000,076,6
2	*Vibrio rumple;* beef peptone agar; 48 hours; 31° C.	0.8 centimetre	0,000,000,020,049	0.000,000,000,030,6
3	*Vibrio elvers;* codfish peptone agar; 24 hours; 37° C.	0.9 centimetre	0.000,000,262	0.000,000,000.355
4	*Vibrio rumple;* fish peptone agar; 24 hours; 37° C.	2.0 centimetres	0.000,001,287,8	0.000,000,000,785
5	*Vibrio rumple;* fish peptone agar; 24 hours; 37° C.	2.1 centimetres	0.000,001,217	0.000,000,000,707

Many remarks have been made as to the color. All agree that it is a bluish-green, and some use the term "whitish" and "yellowish" also in describing it. Weak colonies appear to show the greenish tint most strongly, while it is concerning the

the strongest shining colonies that the term white is most often heard in describing them. Another important factor in assigning a color is the condition of the human eye at the time of observation. Observers who have been in bright daylight, upon coming suddenly into the dark room and looking at the bacterial colonies will see them as somewhat dimmer and bluer or greener in color than later, when the eyes are accustomed to the darkness. Then the light appears greener or yellowish. An observer who has had a good night's sleep and, without going out into daylight, observes the bacterial colonies in a dark room early in the morning is best fitted to determine the visual properties of the light, and it appears nearer white under these conditions than at any other time.

Direct comparisons of two colonies of bacteria of different species by an eye in good condition show that there are some differences in the "greenness" and "blueness," and that these differences are not always due to greater intensity, as is sometimes the case.

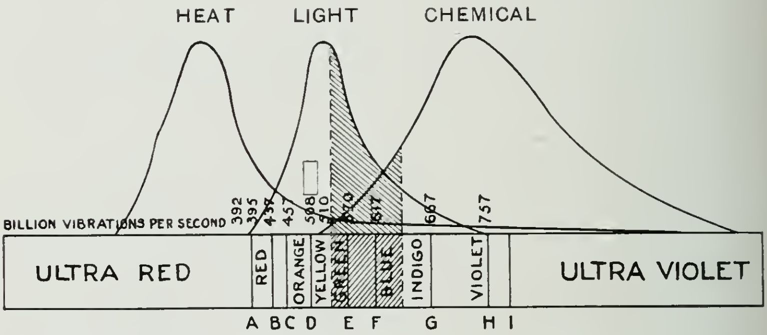
Differences in color are due not only to intensity and to specific dissimilarity but also to the nutrient media on which the colonies are growing at the time. Fischer found that bacteria growing on a medium with the larger proportion of salt gave a light with more blue or green. On the media containing a lesser proportion of salt the tendency was toward a yellowish light. Molisch found that bacteria growing on salted potatoes and human flesh were deeply blue-green, while on dead fish they appeared silver-white. These latter differences seem to be the result of salt proportion and intensity rather than kind of medium. Sufficient work of an accurate nature remains to be done on these favorable organisms with regard to the color of their light.

Gorham has studied the color in the laboratory with physical instruments, and finds that a species secured by him in a butcher shop in Providence, R. I., emits a light with a frequency of vibration ranging from 560,500,000,000,000,000 to 657,600,000,000,000,000 per second. This means that on the spectrum it extends from beyond the line *E* in green to a point midway between *F* and *G* in the blue.

It is continuous within these limits and strongest in the middle part of this extent, becoming weaker at the two extremities of its band.

In Fig. 4 we have a diagram of the three kinds of light as differentiated from each other by their production of heat, their visibility to the eye, and their power to effect chemical change. Or, to put it in another way, we have three curves that show by their rise and maximum point the particular wave-length of light that can do these three things best. The curves cross each other, which means that practically all light waves can do *some* of each. But the maximum points of each curve show that the three effects are still sharply marked off from one another. The shaded area indicates which waves of light are produced by the bacteria, and here we can at once see that the light from these forms is a light that is most able to effect the eye. It is evident that with the least amount of energy, expended a maximum of visibility to the human retina is produced. Also, it is probable that the eyes of other creatures have more or less the same kind of sensitivity as ours, which would make this light most easily seen by them, too.

FIG. 4.



A diagram of the spectrum of light with three curves representing the degree to which the various wave-lengths produce heat, light, and chemical changes. The shaded area indicates the wave-lengths that are present in the average bacterial light. It can be noticed that these rays approach the maximum of visibility and avoid that part of the spectrum that provides heat.

Nature seldom fails to show by the characters of her products what reason there is for their existence, and in this case it can hardly be that the light of bacteria is an aimless by-product. It has been fitted by its course of evolution to be seen, but just by what creatures or for what benefit to the bacteria cannot be said.

The considerable amount of chemical power exerted by the rays coming from the bacteria is indicated by the portion of the chemical curve which is intersected by the shaded area representing the bacterial light. This is also evidenced by the fact that photographs can be taken of the luminous colonies and of objects that these colonies are used to illuminate, as the skull which is shown in Fig. 3, after being photographed by Molisch in the dark room by the light of two gelatin cultures of bacteria.

That some of the rays of the bacterial light are heat rays has been proved by physical instruments only in a few cases. One of the first questions asked by the most superficial observer is always, "Is this light warm or hot?" One cannot detect any warmth by the hand or lip. Nor will the more delicate thermometer show any heat if placed in contact with the shining bacteria. Hulme attempted to detect heat, but his results were negative. To this date, therefore, we cannot positively say that any heat is produced, but, knowing that in the insect a very minute quantity has been proved to be present, and believing that the light in both cases is produced in the same way, we feel some certainty that a very small quantity is produced as an unavoidable by-product in the bacteria during their luminous condition.

It is well known that among the different luminous forms of life there are mechanically two important ways in which the luminous material (luciferine) is used to produce the light. One is its use outside of the cell that produced it (extracellular theory), and the other is its use, *in situ*, in the secreting cell or tissue (intra-cellular theory).

The bacteria are such minute organisms that this rather important question cannot be readily determined. The light from a single individual is so small in quantity that it is not visible under the higher power of the microscope.

Ludwig and Dubois both believed that the light was produced outside of the bacterial cell by luciferine that was secreted inside the cell and passed outside through the pellicle or skin that surrounds each bacterium. They reasoned by analogy, knowing that the bacteria often work in this way in making and using various pigments, toxins, enzymes, etc.

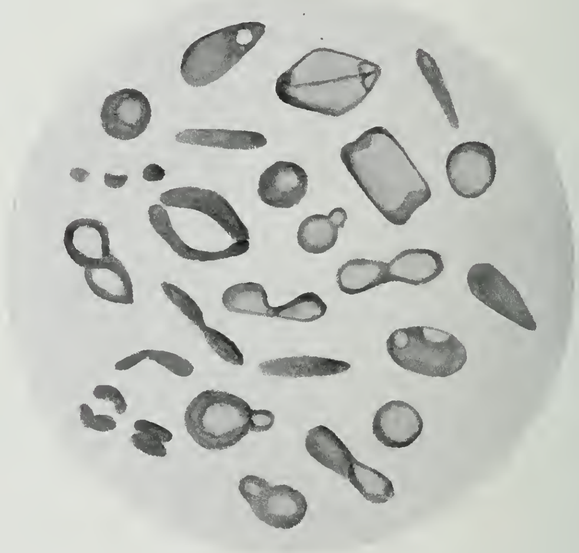
Most observers, however, who have attacked the problem seriously agree that this view is not correct, and that the luciferine is actually oxidized and the light produced inside of the cell. Some of their reasons are as follows:

Lehmann and Sirotinin both filtered actively glowing bacteria through a porcelain filter and found that none of the bacteria free fluid that went through was luminous.

E. Newton Harvey centrifuged bacteria in a fluid medium and found that the light was confined to the solid mass of organisms. This evidence is much like the preceding.

Further, strong but indirect evidence is to be considered in the fact that, when the bacteria are killed by sudden heat, grinding, or pressure, or are ruptured by the osmotic conditions when pure distilled water is poured on them, the light is suddenly extinguished. This points strongly to some mechanical arrangement of the substances that is necessary for light production, and points particularly to the need of an intact pellicle as a condition of luminescence.

FIG. 5.



Some luminous bacteria (*Pseuaomonas*) drawn from a methylene blue preparation on the slide. The inclusions may be vacuoles of the light-producing substance. (Drawn by Miss E. Grace White.)

By some it has been thought that a segregation of the luciferine could be observed in parts of the bacterial body after fixing and staining on the slide. Vacuoles have been observed by the writer as well as by others which seemed to be present in actively luminous cultures and absent in those broods that were not producing light at the time, although healthy and in condition of active multiplication (see Fig. 5).

What, then, is the material that is secreted by the bacterial organisms that is burned in the presence of oxygen and in burning releases its stored energy in the form of 98 to 99 per cent. of light? The work of E. N. Harvey shows us some progress in solving this question.

It shows that the material is not a living one, because we can kill the bacteria by drying, and the ability to glow is left when moisture and oxygen are present again.

Dried bacteria can be extracted with ether (boiling) and toluol, and when dried from these solvents and moistened with oxygen-bearing water they once more glow. Therefore, the matter (luciferine) is not a fat and is not destroyed by ether or toluol.

If we destroy the integrity of the cell by grinding when dried or by cytolizing with distilled water, we destroy the power to illuminate. Evidently there is some structure in the cell that is necessary for the use of the luciferine. Possibly such structure has to do with the separation of two or more substances that are kept separate but brought together to produce light. Further work in this chemical line can probably be better done in some of the more highly specialized light-producing forms to be treated in a succeeding chapter.

(To be continued.)

The Electric Arc in the Foundry. R. KINKEAD. (*Proceedings of the American Foundrymen's Association*, September 28 to October 1, 1915.)—The application of the electric arc in the foundry to what is generally known as the arc-welding process can be employed for reclaiming steel and malleable castings which otherwise would be scrapped, due to defects originating in the casting process, such as sand spots and shrinkage cracks; for the improvement of the quality of steel and malleable castings which would not be scrapped; for the manufacture of steel castings which, owing to their shape, will always crack upon cooling, and for the cutting of gates and shrink-heads.

The effect upon the metal of the heat produced by the arc is the same as that produced by any other method. There is, further, no greater danger of overheating the metal than by any other method used in the foundry. The arc-welder is a motor-generator set which takes power from the supply lines at whatever voltage the power is purchased, either alternating or direct, and delivers direct current at about 75 volts. Resistance ballast is employed to bring the voltage down to 50 or 25, according to whether a carbon or metal electrode is used.

Pilot Flame Ignition of Incandescent Gas Lamps. C. W. JORDAN. (*Transactions of the Illuminating Engineering Society*, September 20–23, 1915.)—The subject of pilot flame ignition of incandescent gas lamps may appear to many to be rather a minor or unimportant detail of the broad general subject of gas lighting, and yet on analysis it will be found to be extremely vital for the successful operation of lamps in practice. Convenience in gas lighting has become a necessity, and many devices have been perfected for securing automatic ignition, in some cases controlled from distant points. Despite the ingenuity shown in the design and mechanical devices for securing automatic ignition, they have not met the practical requirement of service.

Other devices, such as pyrophoric ignition, self-lighting mantles, etc., are not extensively used because of the ease with which the mechanical parts get out of order or on account of the short life of the active material. The simple pilot by-pass and gas-cock actuated by pulling a chain meet the demand for convenience, economy, and service in a most satisfactory manner.

Consumers are often badly misinformed or entirely ignorant of the consumption of gas by pilots. The consumption of a one-burner indoor pilot is in the neighborhood of 1000 cubic feet per year. The consumption by pilots varies from 8 to 20 per cent. of the total consumption with the usual type of burner.

Oerlikon Electric Induction Tire Heater. ANON. (*La Revue Electrique*, vol. xxiii, No. 276, June 18, 1915 (issued Sepember 3, 1915).)—In heating locomotive tires and other like parts for shrinkage operations it has been the practice, in order to avoid the soot and cinders of a coal furnace, to employ the gas blast. While answering the purpose satisfactorily, that type of heater has the disadvantage of requiring a separate burner for each size of tire, and the attendant complexities of the air-blast installation and piping.

With the object of producing a device adapted to pieces of different dimensions and free of special installation for its operation, the Oerlikon Works have recently introduced a special transformer for heating operations of this type.

In its essential features it consists of two cylindrical cores of a U-magnet, with their permanently-attached yoke supported on a suitable truck. Surmounting the cores is a pole-piece arranged to be swung aside about one or the other of the cores and capable of being firmly clamped in magnetic contact with the cores when in use. A primary coil over one of the cores only is employed. In operation the tire surrounds one or the other of the cores. When sufficiently heated the piece is removed by swinging aside the pole-piece. Straight bars may also be heated by arranging them in proximity to the core, with their ends connected with copper cable to form a closed inductive circuit.

RECENT RESEARCHES IN ELECTRICITY AT THE BUREAU OF STANDARDS.*

BY

E. B. ROSA, Ph.D.,

Chief Physicist, Bureau of Standards, Washington, D. C.

BEFORE referring to the recent researches carried out in the electrical division of the Bureau of Standards, it will be desirable to say something of the electrical laboratories and their material equipment, and the different kinds of work included in the electrical division.

The new electrical laboratory building is a substantial structure of brick and stone, occupying a ground area of 190 by about 60 feet, and five stories in height. It is constructed as economically as possible consistent with good materials and workmanship, and proper adaptation to its uses, no attempt being made to make it either ornate or monumental. It cost, including plumbing, heating, lighting, and elevator, but not the laboratory piping and wiring nor furniture, $200,000. A similar sum will be spent for a building of about the same size for the chemical division, plans for which are now being prepared. The three principal buildings which the Bureau had before, together with two smaller ones, cost, without furniture or instrumental equipment, about $600,000. The entire group of buildings, therefore, including the chemical building shortly to be begun, cost about one million dollars, and their equipment represents as much more.

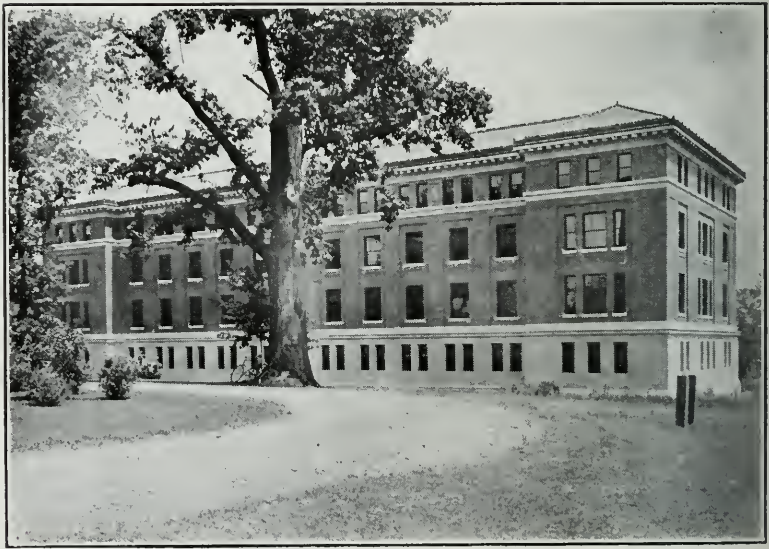
The basement plan of the electrical building is very similar to the other floors. There is a main central corridor, with rooms on either side and a group of rooms at either end. At the north end are the dynamo room and workshop, the former containing a number of motor-generator sets, nearly all built to order, for supplying current for experimental purposes, in addition to the alternating and direct current supplied from the plant in another building. A large number of storage batteries furnish steady current for experimental use, and a small separate building nearby contains transformers for high-voltage work.

---

* Presented at a joint meeting of the Electrical Section and the Philadelphia Section of the American Institute of Electrical Engineers held Thursday, February 11, 1915.

Some of the laboratory rooms in the basement are for the rougher kinds of experimental work, and some are for the most refined work, where steady supports on a bed of sand resting on the earth below the floor level give freedom from vibration. The machines in the dynamo room are all carefully balanced and are carried on a large block of concrete, which also rests on a bed of dry sand, out of contact with the floor or walls of the building. This reduces vibration to a minimum, but some of the most delicate apparatus still detect some vibration, and hence additional precautions are taken with such instruments.

Fig. 1.



Electrical Laboratory—Bureau of Standards.

The first floor is devoted entirely to laboratories for experimental work in electrical and magnetic measurements; the second floor contains more laboratories and also some offices and a conference room; the third floor is devoted to work in photometry and illuminating engineering and the work in radio-active measurements; the fourth floor provides for the work in radio-communication and gas engineering, and contains the main lecture room of the Bureau, seating 300. The attic floor is subdivided into storage rooms and provides one or more rooms for each separate section of the work. The heating is by hot and tempered air, regulated by thermostats, the heating ducts and wiring and piping for the entire building being distributed through a subbasement corridor to four vertical shafts that supply the rooms on each floor. Below this is a vault, where the temperature remains nearly steady throughout the year, at substantially the earth temperature, 30 feet below the surface of the ground.

The work of the electrical division is subdivided into eleven separate sections, as shown below, some of the sections being further subdivided, these subdivisions, however, not being indicated. The first five of these sections were established early in the history of the Bureau. The remaining ones are relatively new.

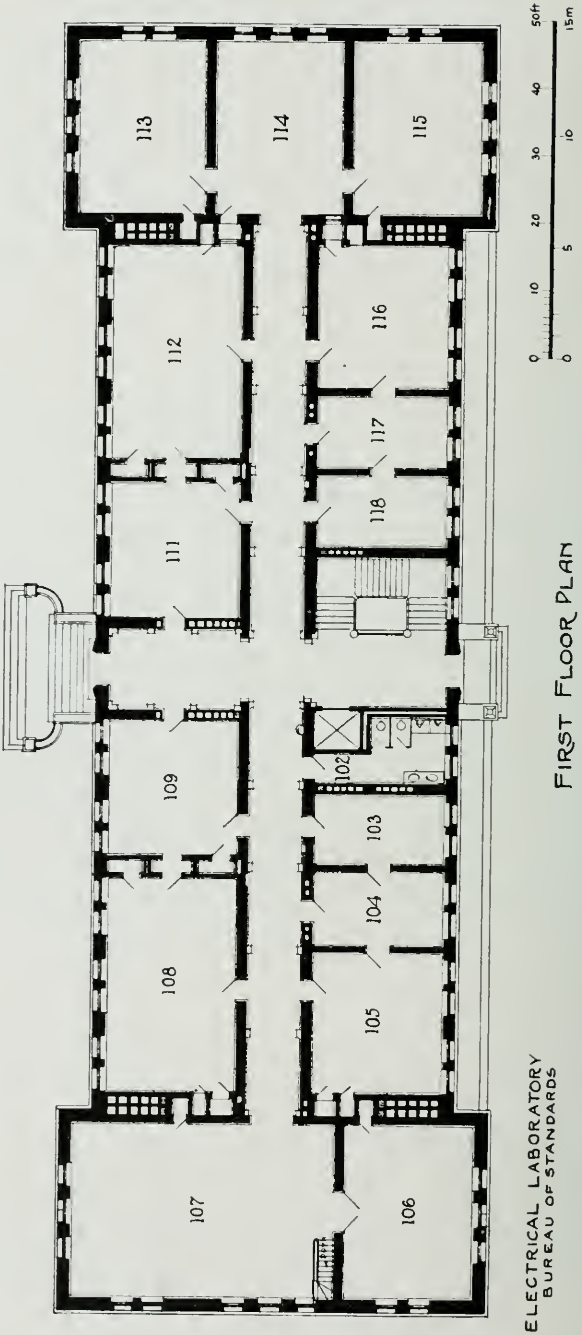
Section 1.—Standards of resistance and electromotive force, and precision apparatus and methods for measurements of resistance and electromotive force.

This work includes the preparation of fundamental standards of resistance (mercury in glass tubes according to the specifications for the international ohm); the maintenance of the fundamental unit by means of sealed wire standards; the derivation of all the other denominations from the one-ohm standards; the study and improvement of methods of measurement; the design of new apparatus for use in such measurements; the testing and certification of standards of resistance and of other precision apparatus; the investigation and improvement of standard cells for standards of electromotive force; and the testing and certification of such cells.

Section 2.—Standards of inductance and capacity and of radioactivity; absolute measurements of current, resistance, and other electrical quantities; and the investigation of the silver voltameter as the fundamental standard for the international ampère.

In this section a large amount of work has been done on the methods of measurement of inductance and capacity; the improvement of inductance and capacity standards and the testing of such standards; measurement of the capacity and inductance of instruments; the absolute measurement of current by means of current balances; the determination of the ratio of the electrostatic and electromagnetic units; the investigation of the silver voltameter

Fig. 2.



Electrical Laboratory, First floor plan.

with a view of obtaining the highest degree of reproducibility, and of obtaining information on which to base international specifications; the calculation of inductances from their dimensions; and the investigation of radio-active measurements and the testing of radium and other radio-active substances.

Section 3.—Electrical measuring instruments, including ammeters, voltmeters, wattmeters, watthour meters, phase and frequency meters, current and potential transformers, batteries and other instruments and apparatus used especially in commercial and engineering work.

This work includes the theory and practice of a large part of the measurements and testing of electrical engineering, as opposed to the more precise measurements with standards and the precision apparatus included in Sections 1 and 2. The work, however, involves a thorough knowledge of the theory of instruments and measurements, and many refinements in the conditions of the tests. Some of the work is of a research character even when it is nominally a test, for many of the tests are new, and frequently require the development of the methods and sometimes even of the instruments employed.

Section 4.—Magnetic measurements, including the development of standards and methods of measurement; the testing and improvement of instruments for magnetic measurements; the testing of samples of magnetic materials for permeability and hysteresis; and the investigation of the relation between the magnetic and the mechanical properties of magnetic substances.

The work done in this section has covered a wide range and exerted a great influence on the methods and instruments used in this country in the commercial testing of iron and steel. The accurate measurement of magnetic quantities is beset with peculiar difficulties, one of the chief being the more or less uncertain variation of the quantity being measured. The dependence of the magnetic properties of a substance upon its mechanical properties and the heat treatment it has received has long been studied, but much remains to be learned, and the Bureau has been working on the subject for some time.

Section 5.—Photometry and illuminating engineering, including the methods and instruments of photometric measurements; the testing of photometric standards (both flame standards and electric lamps used as standards); the investigation of light sources, especially those used as primary or secondary standards; the study and testing of lighting fixtures and accessories; and the inspection and testing of electric lamps for the government.

This work covers a very broad field, from the research concerned with the development and maintenance of standards to the inspection and life-testing of lamps to determine their quality as light sources, and whether they conform to standard specifications. By supplying standardized electric lamps to the manufacturers and testing departments of cities, commissions, and operating companies, and testing and certifying gas-flame standards for gas companies and inspection departments, the Bureau has brought about a uniformity in candle-power measurements which did not exist before.

Section 6.—Radio-communication or wireless telegraphy, including the investigation of instruments and methods of measurement; the design and improvement of measuring instruments; the testing of instruments used for the measurement of wave frequencies and logarithmic decrement; the testing of high-frequency ammeters and other high-frequency instruments; the design of signalling apparatus for various branches of the Federal Government; and coöperation with the Bureau of Navigation in the administration of the Federal laws regulating the use of wireless apparatus.

This work includes many of the most important aspects of signalling by the use of electromagnetic waves of high frequency, as well as the investigation and testing of instruments for quantitative measurements. The work at the Bureau is relatively new, and is not as well established as most of the work previously mentioned, but enough has been done to show the advantage and desirability of greatly extending it.

Section 7.—Electrolysis mitigation and other problems connected with electric railway operation. This and the next four sections pertain to public utility service, and are carried on mainly by means of special appropriations.

Electrolysis mitigation is one of the most urgent problems in connection with electric railway operation, and for this reason it was taken up first. This work includes laboratory investigations, field studies and surveys, and special investigations as to methods of keeping street railway current out of the pipes, cable sheaths, and underground structures which are injured or destroyed by electrolytic corrosion. Other problems which remain to be taken up in this field have to do with (1) the quality and adequacy of the service, (2) the efficiency and cost of service, (3) the safety of service and methods of reducing accidents to employees and the public, and (4) studies of regulation, inspection, and administration.

Section 8.—Standards for electric lighting and power service, including a study of what constitutes safe and adequate service under different conditions, and what requirements can be made of different classes of utility companies regarding the uniformity of voltage, continuity of service, accuracy of meters, attention to complaints, etc.; and also a study of various problems of street lighting. The investigations are of a different character from those in the preceding sections, but are nevertheless important and require a scientific and unbiased attitude of mind on the part of the investigators.

In this work the coöperation of the state commissions, municipal inspectors, operating companies, and committees of engineering societies has been obtained, and the work has the indorsement both of the commissions and other representatives of the public and of the utility companies.

Section 9.—Standards for safe operation of the electrical utilities, including the formulation of rules applying to the construction of electric lines (overhead and underground) and the installation of electrical apparatus and machinery.

This work includes the preparation of a National Electrical Safety Code, which is having the coöperation of all the electrical utility companies, including the light and power, street railway, telephone and telegraph companies, and also the steam railway companies, which are concerned partly because they use electric signalling systems and partly because the lines of other companies cross their tracks and signal lines so frequently. The work includes also the questions of inspection of electric power stations, transmission and distribution lines, and the apparatus and machinery employed in the industrial uses of electricity. The work will also include the periodical revision of the Safety Code after its issuance, and coöperation with the National Fire Protection Association in the revision of the Fire Code.

Section 10.—Standards for gas service and safety, including the study of the elements of good service; the legal requirements that can fairly be made of gas companies; the inspection and testing methods to be used by state commissions and municipal officials; and a national gas safety code for the use of the manufacturers, distributers, and users of gas.

This work has been in progress for six years, and has progressed further, so far as standards for service are concerned, than the corresponding work in electric service. The Safety Code is just being taken up.

A large amount of research and testing has been carried out in connection with this work, in which the chemical and heat divisions have shared. The methods of testing gas for heating value, candle-power, chemical purity, and pressure are fully treated in various publications, and some state commissions and city officials have been assisted in formulating rules for local use.

Section 11.—Standards for telephone service, including the specification of what is good performance by transmitters, receivers, and other parts of telephone equipment and of the system as a whole, together with studies of the regulation of telephone service by public authority.

This work is just being taken up, and so far nothing has been prepared for publication. It is one of the most important fields of public utility service, and offers an opportunity for scientific and engineering work of great importance.

Having stated the various lines of work carried on in each of the separate sections of the electrical division, we may now consider some of the particular investigations recently completed or still in progress. Examples will be given under each section, but time will not permit mentioning all.

THE MERCURY OHM.

The unit of electric resistance is defined by international agreement as the resistance of a column of mercury in a glass tube kept at the temperature of melting ice, the length of the column being 106.3 cm. and the mass such that the cross-section is about 1 sq. mm. The difficulty of preparing such standards of resistance is so great that several glass tubes are prepared with suitable terminals and then filled repeatedly, the electric resistance being taken after each filling. The greatest care is taken in measurements of the length of the glass tubes, in filling so as to exclude the slightest film of air between the mercury and glass, in securing uniform temperature throughout (accurately at zero) and in getting the resistance in terms of wire standards with the highest possible precision. Every possible source of error must be avoided in order that the mean of several series of determinations shall be correct within two- or three-thousandths of one per cent. when all sources of error are included. Such resistance standards are set up only at standardizing laboratories in a few countries of the world, and by agreement among these laboratories the international ohm is taken as the mean of the values found. A paper describing the work at the Bureau on this subject has recently been completed.

WESTON NORMAL CELLS.

The standard of electromotive force adopted by international agreement at the London Electrical Congress of 1908 is the Weston normal cell. Specifications for its preparation call for the use of pure materials, but when measurements are made to the millionth of a volt it is found that appreciable differences occur in different cells, all of which are made from equally pure materials. Investigations extending over several years have shown that these small differences are chiefly attributable to variations in one of the chemical substances; namely, the mercurous sulphate. This substance may be prepared with sufficient purity either chemically or electrochemically, but the results obtained for the electromotive force of the cell are different when materials are used which have been prepared in slightly different ways, and they also differ appreciably with different lots prepared in the same way if the details of the preparation have been slightly varied. For example, it is known that the electromotive force varies appreciably between cells containing electrolytic mercurous sulphate prepared by the use of direct current from the values when electrolytic mercurous sulphate is used which has been prepared by means of alternating current. Further, it has been found that mercurous sulphate prepared electrolytically by means of alternating current gives cells of very constant electromotive force, but different samples prepared in somewhat different ways do not quite agree. The study of these differences has been actively in progress for some time at the Bureau. It has been learned that the electromotive force of the cell varies according to the strength of the current that has been used in preparing the electrolytic mercurous sulphate, and also according to the temperature of the solution and its concentration and the method of its stirring, the explanation being that the size of crystals of mercurous sulphate is affected by variations in these particulars of treatment. This investigation illustrates how much additional work is involved in extending the desired accuracy by another decimal place. If we desired only reproducibility of the standard cells to the hundredth part of one per cent., it would be very easy to prepare the cells. A reproducibility of a thousandth of one per cent. is much more difficult and requires enormously greater precautions and labor. To try to get reproducibility to a few millionths of a volt is still more difficult. However, the endeavor to secure the highest possible reproducibility leads to the discovery of hitherto unsuspected sources of differences and gives a more complete knowledge of the theory of the cell. We believe that the result of this investigation will enable official specifications to be drawn which will be so much more complete than those heretofore used that the Weston cell as a standard of electromotive force will be greatly improved.

The unsaturated Weston cell is used in ordinary electrical measurements instead of the standard form which is saturated, the reason being that the former has a smaller temperature coefficient. The Bureau is investigating this type of cell also with the hope of being able to prepare cells that will be more constant and in better agreement with one another, and therefore more useful for precision measurements.

GALVANOMETERS.

Another investigation which has been in progress for several years, and which has yielded very valuable results, relates to sensitive moving-coil galvanometers. In comparing resistance standards with the highest possible accuracy, and without using enough current to change their temperature appreciably, it is necessary to have galvanometers of extraordinary sensitivity. Moving-coil galvanometers of suitable characteristics are so much more convenient in use than moving-needle galvanometers that they are almost always used in this work. The need of galvanometers of maximum sensitivity has led to a thorough study of the theory and design of such instruments, and a number have been built in the instrument shop of the Bureau which have been of higher sensitivity than any which we possessed before, notwithstanding that we had the most sensitive instruments to be purchased anywhere in the world. A paper on the theory and design of such galvanometers has been prepared. This paper discusses the mathematical relations between the operating constants of the galvanometer and the factors entering into its construction, such as the magnetic field and the shape, size, and kind of material of its parts. Directions are given for the construction of galvanometers for various special uses.

ALTERNATING-CURRENT GALVANOMETERS, ETC.

Alternating-current bridges are much used in electrical measurements, and it is necessary to have some detector of high sensitivity responding to alternating current of the frequency used in the bridge. Sometimes a telephone is used, sometimes a tuned galvanometer (also called a vibration galvanometer), and sometimes an electrodynamometer having a separately-excited electromagnetic field. For alternating currents of low frequencies the telephone is not sensitive and the vibration galvanometer is generally used. The latter, however, is not as sensitive as is desirable in some kinds of work. A careful study of the problem, making use of the experience gained in the construction and use of sensitive galvanometers for direct current, led to the development of an alternating-current galvanometer of extremely high sensitivity, and a paper describing the work has been prepared for publication. These galvanometers have been made as sensitive as the best direct-current galvanometers, and while, in some respects, not as convenient to use as the usual form of tuned galvanometer, they are much more sensitive and will be very useful for certain kinds of work.

An improvement in the accurate measurement of temperature has been made possible by a new potentiometer designed and constructed recently. The settings of the potentiometer are varied by moving a high-resistance shunt from one set of coils to another. Thermal electromotive forces generated at the sliding switches do not affect the measuring circuit.

THE SILVER VOLTAMETER.

The International Electrical Congress at London in 1908 adopted the international ampère as a second fundamental electrical unit (the first being the international ohm), and defined it as a current which will deposit 0.00111800 gramme of silver per second from an aqueous solution of silver nitrate under certain conditions, some of which were not specified. The silver voltameter had been subjected to many investigations during the thirty years preceding the London Congress, and many papers have been published in various countries concerning it. However, the differences in the results obtained, and in the opinions of different investigators as to the causes of these differences, were such that detailed specifications could not be agreed upon at the time, and they were left to be developed later. In 1910, an International Committee assembled in Washington, at the Bureau of Standards, for the purpose of investigating the instrument further. This committee represented the national standardizing institutions of Germany, France, and England, as well as the Bureau of Standards. As a result of two months' continuous work on the subject in Washington, a report was prepared which gave considerable further information concerning the use of this important electrical standard. However, there still remained some obscure causes of variation, and the Bureau of Standards has continued the investigation up to the present time, and has published several papers giving the results of the work as it progressed. During the current year further investigations are being made, some of which are in coöperation with Professor Hulett, of Princeton, and others of which are for the purpose of checking results found at Harvard. The outstanding sources of differences are so small that measurements must be made to within about a thousandth of one per cent. It is hoped that in the near future complete official specifications may be prepared which will be adopted internationally.

INDUCTANCE AND CAPACITY MEASUREMENTS.

The resistance and inductance of bimetallic wires is another subject which has been under investigation at the Bureau. Wires made up of a steel core, with an outer copper sheath, are used in electric power transmission and in telephone work. The resistance and inductance of such wires to alternating current vary with the frequency of the current, and it was of considerable importance to determine the law of such variations. The investigation resulted in the derivation of formulas for calculating the variation of resistance and inductance, and the results of the calculations were checked by measuring them experimentally. The magnetization of the steel core by means of the current flowing through it is circular, and a study was made of the relation between the circular and longitudinal permeability of wires.

The Bureau has made a very thorough investigation of the measurement of electric capacity, and of various types of condensers with respect to the relation between their capacity and the energy expended upon them when submitted to definite alternating electromotive forces. Important improvements in the quality of mica and paper condensers have been made as a result of this investigation. Recently a set of standard air condensers has been built which will be of great use in research work and precision testing, since they are more constant and of much larger capacity than the condensers previously used for the purpose. Special types of air condensers have been designed and used in connection with measurements in radio-telegraphy, the shape of the plates being such as to facilitate the direct reading of decrements.

RADIUM.

One of the most recent lines of work taken up by the Bureau is the investigation and measurement of radium and radio-active substances, including radium emanation, radium minerals, and radio-active waters. The Bureau has a standard specimen of radium which is standardized in terms of the international standard preserved at Paris, and makes a large number of measurements of sealed radium specimens to determine by means of their gamma radiation the quantity of radium contained. Various radium products and preparations for therapeutic use are also submitted to the Bureau for test. It is important that physicians using radium shall know definitely the quantity contained in their specimens in order to be able to correlate the results obtained with the strength of radiation employed. Also, when radium sells at the rate of three and one-half million dollars an ounce, it is important that the purchaser of a specimen should know how much radium is actually contained in the brown powder, some of which may be sand which without measurement may be passed as radium. It is also important to subject so-called therapeutic preparations of radium and radium salts to a test of actual measurements in order to discourage fakes and frauds. The Bureau has made a very careful study of methods of measurement, and has a considerable instrumental equipment for such measurements.

ELECTRICAL MEASURING INSTRUMENTS.

Several investigations on the testing of current and voltage transformers have recently been made and the results published; other papers in connection with the testing of electrical measuring instruments have also been published. A thorough study of such instruments has been made in connection with the testing work, and recently a second edition of our circular, which is really a treatise on that subject, has been prepared for publication. The Bureau's facilities for the testing of such instruments are very complete. Alternating current of a wide range of frequencies and adjustable wave-form is available for such tests, being delivered from machines which can be run at constant speed, giving a remarkably constant frequency of alternation in the current. Instruments may be maintained at constant temperature which may be regulated at any point between freezing and such temperatures as prevail in engine-rooms, so that change of frequency, or change of wave-form, or change of load, or the effect of a strong magnetic field upon it, or any one of many variations of conditions which may arise in practice, can be separately determined. Inasmuch as all makes of instruments are submitted either by the manufacturers or their customers, and in many cases extended investigations are made, the Bureau is in possession of a very large amount of detailed information on the performance of various kinds of electrical measuring instruments which has never been published. Bureau Circular No. 20 is a discussion of such instruments, based upon the experience of the Bureau for fourteen years, since its establishment, together with criticisms and suggestions received from a number of the most experienced manufacturers and engineers in the country. This is one of the most carefully prepared and useful publications of the Bureau.

In the testing of instruments used in high-voltage and heavy current measurements the Bureau is well equipped. A special building contains transformers of 5000, 25,000, and 100,000 volts, which furnish current for the calibration of high-voltage measuring apparatus and for testing and investigation. A battery capable of furnishing 5000 ampères at steady voltage is used in the testing of heavy current instruments, and permits current-carrying standards to be certified and their temperature coefficient studied.

MAGNETIC INVESTIGATIONS.

In the magnetic work the Bureau has made very thorough investigations of methods of measuring permeability and hysteresis loss, including apparatus for precision measurements and also the more convenient and rapid apparatus for commercial use. A great deal of attention has been given to the preparation of standards, and this has involved a thorough study of the methods of bringing specimens of iron or steel into a standard initial condition so that when magnetized by a certain procedure the result of magnetization will always be the same. This proved to be one of the most important as well as one of the most difficult conditions to meet in the preparation and use of standards. Comparisons have been made with the magnetic standards of the standardizing laboratories of Germany and England, so that for the first time in the history of magnetic measurements we are assured of international uniformity in numerical expression of the results of measurement.

Recently a thorough investigation of a particular type of permeameter has been completed, an instrument which has been extensively used for commercial testing, but which is capable of giving results differing considerably according to the conditions of the test. This investigation will lead to improvements in the results obtained by such instruments.

Another recent investigation in magnetism at the Bureau is concerned with the temperature coefficient of permeability. Heretofore temperature has usually been neglected in the measurement of permeability, but it has been shown by this recent investigation that the temperature coefficient may be as great as one-third of one per cent. per degree, and, inasmuch as the temperature of the specimen is subject to variation not only from varying room temperature but also from the current used in magnetizing the specimen, the uncertainty in the temperature, if it is not carefully measured, may be a good many degrees, and the effects upon the result may be several per cent.

Another investigation of considerable practical importance has been a study of the core loss in specimens of iron at very high inductions, under which conditions the measurements are relatively difficult. As a result of this investigation it is now possible to obtain satisfactory results when the limits of the magnetic induction are extended from 10,000 to 15,000 units.

Still another investigation, upon which a large amount of work has been done, is the study of the relation between the magnetic and the mechanical properties of magnetic substances, and the practical application of this work to the detection of flaws in steel rails or other magnetic materials. Apparatus has been developed by means of which photographic records show the location of such hidden flaws under some circumstances, and one question that has been considered is whether it will be possible to utilize such a method in practice as a check upon the quality of steel rails. However, the results so far obtained do not show that this is commercially feasible, although further work may make it seem more practicable. More information, however, on the subject of the relation of the magnetic and mechanical properties of materials cannot fail to be of great scientific interest, and without doubt will prove of practical value also.

PHOTOMETRIC INVESTIGATIONS.

As photometric standards for use in testing the quality of gas or the illuminating power of light sources burning gas, flame standards are usually employed. The candle-power of such flame standards varies with the atmospheric conditions surrounding them. The lamp itself is, of course, not a standard, but a lamp made according to certain specifications, burning a fuel which conforms to other specifications, in an atmosphere which also conforms to definite specifications, and, handled in a certain definite way, will give the normal candle-power, and the entire combination constitutes the standard. Variations in atmospheric humidity and variations in atmospheric density or in the composition of the atmosphere all affect the candle-power of the flame. The Bureau has made very extended studies of the effect of atmospheric moisture upon the candle-power of flames, and has made it unnecessary to determine the effect of vitiation of the atmosphere from the products of combustion by securing perfect ventilation in the lamps under test. However, the effect of varying atmospheric density due to ordinary fluctuations of the barometer, or due to varying altitudes above sea level, had never been measured with sufficient accuracy until the recent work at the Bureau. It was first proposed to make several series of measurements upon flame standards at several stations located at different altitudes above the sea level from 3000 to 10,000 feet, and to calculate from these measurements the rate of change of candle-power with the change in barometric pressure. It was, however, found possible to build an apparatus in which these flame standards could be burned in the laboratory in such a way that the air could be circulated rapidly through the apparatus at any desired constant pressure (within rather wide limits) and the candle-power measured as accurately as when the flame is burning in an open room. A long series of measurements of this kind on various light sources has furnished accurate determinations of the rate of change of the light with the atmospheric pressure, which is found to be different for each different light source; and with gas lamps it varies for the same gas with different types of burners. It is now possible for the first time to certify not only the normal candle-power of a pentane lamp used as a standard, as heretofore, but also to state what its candle-power will be at any particular altitude above sea level. The effect of atmospheric humidity has also been redetermined in this apparatus, the results agreeing very closely with those previously found.

Another investigation which has been in progress in the Bureau for some time, which is of very great practical importance, is the problem of determining the ratio of the candle-power of light sources of different colors. A photometer is an instrument used to compare the intensity of different light sources, and accurate and consistent results may be obtained when the lights have the same color, but when the colors differ appreciably it is difficult to say when two surfaces are illuminated to the same intensity. Accordingly, different observers will differ as to the value to be assigned to a given light source in terms of a standard of a different color. These differences are in part accidental and in part systematic. The accidental errors may be largely eliminated by having observers take a large number of observations. The systematic readings depend in part upon the variation in the eyes of different observers. The standardization work that the Bureau has done upon lights of different colors has been based upon results of a considerable number of observations, and we have had very satisfactory agreements in making intercomparisons with the National Physical Laboratory of England upon the candle-power of certain tungsten lamps rated in terms of carbon lamps burning at 4 watts per candle. Nevertheless, the work is not yet upon an entirely satisfactory basis, and the investigation is being continued.[1]

One of the important results of this work is the discovery that tungsten lamps of different makes and different types have very closely the same characteristic curves which connect candle-power with voltage, so that it is possible for a given lamp to be rated for candle-power at several different voltages, which correspond to several different colors, and one lamp may thus serve the place of a series, and furnish means for testing lights of appreciably different color without a color difference in the photometer. The characteristic curves are expressible by a simple mathematical equation.

Another investigation of interest and importance in connection with modern lamps has had to do with the measurement of the candle-power of gas-filled tungsten lamps. It has been found that the candle-power and efficiency of such lamps vary when they are rotated from the value they possess when stationary. Partly for this reason and partly because of their very white color and large candle-power units, the photometry of such lamps has been especially difficult. For several years the Bureau has prepared photometric standards by seasoning incandescent lamps and rating them as to efficiency and candle-power, so that the manufacturers and testing laboratories of the country are supplied with standards in very close agreement. These electrical candle-power standards are so much more uniform and reliable than any so-called primary standards as yet developed that they are, in effect, the primary standards of the country. Flame standards built according to specifications vary so much that it is necessary for each to be separately standardized in terms of the more constant electrical standards.

RADIO-COMMUNICATION.

The work of the Bureau on radio-communication, or wireless telegraphy, as it is more commonly called. dates from the time when a Federal law was passed requiring passenger ships to be equipped for radio-communication and to have an auxiliary source of power that will be sufficient for signalling 100 miles when the main source of power is disabled, and also requiring that the wave-lengths employed in such signalling shall be not more than 600 metres, and that the damping of the electromagnetic waves sent out should be not greater than corresponding to a logarithmic decrement of 0.2. The administration of this law rests with the Bureau of Navigation, but the Bureau of Standards serves as its scientific adviser, and designs and tests apparatus for its inspection service. The instruments used by the inspectors for measuring wave-lengths and logarithmic decrements were designed at the Bureau and built according to our specifications, and have been calibrated, and from time to time recalibrated, at the Bureau. We have also designed and superintended the construction of complete radio equipments for several ships, both of the Bureau of Navigation and of the Bureau of Lighthouses.

---

[1] A more complete investigation of this subject has been undertaken since the date of this lecture, and important results already obtained were recently communicated to the Illuminating Engineering Society.

An investigation of radio interference was made by the Bureau on the Pacific coast in answer to complaints that a commercial station was interfering with the use of wireless by the Navy Department.

Problems in connection with wireless signalling are under investigation at the Bureau with the hope of increasing the usefulness of this important means of communication in fogs at sea. Other investigations have to do with the high-frequency testing of inductance coils, condensers, ammeters, and other instruments used in the transmission and receiving of wireless messages.

PUBLIC UTILITY INVESTIGATIONS.

The research work that has been carried on in connection with the various lines of public utility work has been partly in the laboratory and partly in the field, supplemented by extensive correspondence. Methods have been investigated for testing gas for candle-power, heating value, chemical purity, etc., and for testing electrical instruments used in measuring the service rendered by electric companies. A large number of investigations have been made in connection with electrolysis mitigation upon soil resistance, the corrosion of pipes buried in the ground, the effectiveness of waterproofing and insulating compounds in actual use, the different kinds of bonding employed in electric railways for securing an electrical connection between rails, the electrical resistance of different kinds of roadbeds, the relative corrosion due to alternating currents and periodically reversed direct currents as compared with continuous direct currents on underground structures, and other similar questions. In field studies, inspections have been made and electrolysis surveys conducted in a number of cities, and reports prepared showing how conditions could be improved, what the effect would be upon operation, and what the net cost of securing freedom from electrolysis damage would be. By correspondence, information has been collected with regard to practice of utility companies in different lines of work, the requirements and inspections made by cities and state commissions, and other information gathered that would be useful in the preparation of a complete discussion of the subject of standards for gas or electric service.

The work in connection with telephone service is only just being taken up.

Another important line of study has been in connection with the life hazard in electrical practice, in the preparation of a National Electrical Safety Code. This work has been in progress for more than a year, and a very large amount of information has been gathered on the subject of safe practice in the production, distribution, and utilization of electricity. Statistics with regard to accidents are collected, coroners' reports upon fatal accidents studied, causes of serious and fatal accidents determined so far as possible from reports to state commissions or by special correspondence with the companies concerned, and such results have all been utilized in the formulation of rules for safe construction and operation. Although this investigation does not involve much experimental work, it is nevertheless a very important example of really scientific research work. The ultimate aim of deriving from it a truly National Safety Code that can be adopted by the public service and industrial commissions in the various states and by cities, as generally as the Underwriters' Fire Code is adopted, is of great interest and importance.

The preparation of a National Gas Safety Code has also been undertaken. This will not only cover the ground of the Electrical Safety Code, but will also include the fire-hazard side of the question. The Gas Safety Code will be concerned with the manufacture, distribution, and utilization of gas and will be divided into five parts. The first will have to do with the manufacture of gas, the second with its distribution, the third with the design and construction of gas appliances, the fourth with the piping of buildings and the installation of appliances, and the fifth with the use of gas and the care of appliances. This investigation involves the collection of information from the industry, the study of rules formulated by companies and by municipal inspection departments, and the experimental study of gas appliances, in coöperation with manufacturing and operating companies.

Another problem of engineering interest and importance which the Bureau has been studying recently is that of the service rendered by electric light and power companies, and the specifications for good service that can be set up by public service commissions or cities that have the authority to regulate such service. The question as to what is safe and adequate service under certain conditions is one that requires very careful study and familiarity with practice in many places. The requirements that can be met as to steadiness of voltage and continuity of service offered under different conditions can be fixed only after careful consideration of best current practice under defined conditions. Ordinances have been prepared for cities of different sizes and for plants operating under different conditions, and rules suitable for adoption by state commissions have been formulated. This work has been done in close coöperation with the public utility companies and the state commissions, and is an example of a different kind of investigation from most of those already cited. It is, however, of just as great practical importance and public interest.

This brief survey of the current research work of the electrical division of the Bureau of Standards indicates that it covers a wide range of subjects, so wide indeed that a much larger force is needed to cover the field adequately and satisfactorily. It is hoped that the scientific and commercial value of such work will come to be more generally recognized, and that a more ample provision may be made for it in the near future.

Marine Semi-Diesel Engines. ANON. (*The London Times Engineering Supplement,* No. 490, August 27, 1915.)—So rapid has been the development of the semi-Diesel or hot-bulb motor that it now practically holds the field for all types of motor craft in which the engine installation is anywhere between 100 and 600 horse-power. Below the former figure the paraffin engine is still very largely used, while above 600 horse-power the Diesel engine is better, as a rule, since even this power necessitates a twin-screw arrangement with a hot-bulb installation.

The employment of hot-bulb engines for barges and cargo-carrying coastal vessels has long been common, and during the past year it has gained considerable ground in its application to tugs, for which it is eminently adapted. Some such vessels are now to be seen on the Thames, and others have recently been ordered. In the opinion of those who have had most experience in both steam and motor tugs of this type, it is probable that the steam-driven tug will in course of time give way entirely to that equipped with hot-bulb engines, since the economy to be effected by the employment of the cheap heavy oil suitable for hot-bulb motors will render the steam tug in comparison far too expensive to operate.

Voice Carried 4900 Miles by Radio. ANON. (*Electrical World,* vol. 66, No. 15, October 9, 1915.)—With a few notable exceptions, radio-telephone workers of the past have been so much given to making extravagant claims for their various instruments, and then failing to accomplish anything even remotely resembling the original promises, that it is gratifying to find a real accomplishment in the art not previously advertised.

The human voice was successfully carried across the continent by wireless telephony on September 29 by the American Telephone and Telegraph Company. Speech transmitted from the radio station at Arlington to Mare Island, San Francisco Bay, was also heard clearly at the Pearl Harbor station in Hawaii, 4900 miles away.

It had been known for some time that the American Telephone and Telegraph Company and the Western Electric Company had been experimenting in radio-transmission from the Arlington station of the United States Navy Department, the aërial of which was loaned for that purpose. That the results which would be secured were to be of such great importance and interest was hardly suspected, however. After a period of preliminary experimentation, in which the special apparatus of the telephone company was connected to the aërial supported from the three tall towers at Arlington, on August 27 a telephonic test was made from there to Darien, Isthmus of Panama, 2100 miles away. Satisfactory speech was actually transmitted between the naval stations at these points, and greater likelihood of success for the anticipated transcontinental test was thus indicated.

EARLY MUNICIPAL WATER WORKS AT PANAMA.*

BY

CARLETON E. DAVIS, C.E.,
Chief, Bureau of Water, Philadelphia.
Member of the Institute.

MUNICIPAL engineering problems of the early period of American operations on the Isthmus of Panama occupy a more important place in the history of the canal than is indicated by the relative magnitude of the work involved. As an item in the total construction required for the successful completion of the canal, the municipal works are insignificant; but as an essential step in the sanitary renovation of the Canal Zone and the adjacent cities of Panama and Colon, these works must be accorded a position of considerable prominence.

It is the intention of this paper to record briefly certain phases of the water works construction at Panama, from the inception of the American work up to the time when yellow fever was practically eliminated from the Isthmus, or from July, 1904, to October, 1905.

The treaty between the United States and the Republic of Panama under which the United States acquired the right to construct the canal ceded to the United States the Canal Zone, with full sovereignty therein. The treaty likewise gave to the United States control of all health matters in the adjacent cities of Panama and Colon, and provided that the United States should construct water and sewerage systems in those cities, stipulating that rates collected should be sufficient for the amortization of the cost, principal and interest, in fifty years.

The formal transfer of the canal properties from the French Company to the United States took place May 4, 1904, and shortly thereafter the Isthmian Canal Commission proceeded to exercise the rights conferred by the treaty. Mr. John F. Wallace, Chief Engineer, and Col. William C. Gorgas, Chief Sanitary Officer, arrived on the Isthmus the latter part of June, and active steps in organization, sanitation, and preparation to build the canal began immediately.

---

* Abstract of a paper presented at the meeting of the Mechanical and Engineering Section, held Thursday, March 4, 1915.

When this work started, Panama City had a population of about 20,000. It had no public water supply. The inhabitants depended upon cisterns and an irregular dispensing by wagons which brought water from certain wells on the outskirts of the town. The city had no sewer system, although a few inadequate underground drains existed which were more of a sanitary nuisance than a benefit.

Colon had a population of about 8000. The Panama Railroad Company had a water supply in that city capable of delivering about 60,000 gallons a day. But, as this water was required for railroad, steamship, and allied purposes, the residents depended upon cisterns and similar collectors, as was the case in Panama. The railroad supply, moreover, was drawn from a watershed area of twenty-four acres back of Mount Hope, on which about fifty people were resident. As no sanitary precautions were taken, the use of the water for domestic purposes was at least questionable.

The Panama Railroad Company had installed in Colon one or two small sewers serving their works, but the city proper was even more lacking in sanitary drainage facilities than was the city of Panama.

Several of the construction towns along the line of the canal, such as Paraiso, Culebra, Empire, Gorgona, and Bohio, had been furnished by the French Company with water from nearby springs or streams. These supplies were incomplete and inadequate, being limited to providing water for bathing at a few buildings. The chief reliance was tanks and cisterns, as in the cities of Panama and Colon.

In brief, the lack of public water supplies resulted in tanks, cisterns, barrels, and similar receptacles being universally prevalent throughout the entire line of the canal, with a great concentration of such containers at the critical terminal points of Panama City and Colon. These receptacles formed ideal breeding places for the *Stegomyia,* or yellow-fever transmitting mosquito. These mosquitoes do not breed in the open swamps or larger bodies of water, but require the protection of buildings, grass, and foliage. Until household water containers could be eliminated by the substitution of modern water works and the accompanying sewers, it was a practical impossibility to exterminate the *Stegomyia.* Yellow-fever control at the Isthmus, then, was very largely a question of the early introduction of water supplies.

Very little yellow fever existed on the Isthmus when the Americans assumed control. The entire population was practically immune. With the arrival from the United States of hundreds of non-immunes, however, the situation changed. Yellow-fever cases gradually increased, until in June and July of 1905 the conditions approached those of an epidemic. At this critical period the laying of water mains in Panama City had sufficiently advanced to permit turning on the supply, with an accompanying decrease in cisterns and other water receptacles. The drop in yellow fever was at once apparent, as is shown in the following table:

	Deaths
July, 1904–January, 1905, inclusive	13
February, 1905	6
March	4
April	2
May	8
June	19
July	13
August	9
September	4
October	2
	80

Only the infinite patience, unremitting efforts, and constant vigilance of Colonel Gorgas and the sanitary corps working under his direction, coupled with skill and experience, prevented a veritable epidemic, handicapped as they were by the presence of thousands of mosquito-breeding foci. With the elimination of these breeding places, the triumph of the sanitarian was complete.

From the beginning, Panama City was looked upon as the centre from which the introduction and spread of yellow fever was most to be feared. This city had constant communication with South American ports where yellow fever was endemic, and a single imported case escaping quarantine regulations would be sufficient to spread serious trouble. The water supply for that city was therefore considered of primary importance. It was not a question of the best system, but a matter of how soon a suitable supply could be introduced. The selection of a permanent source could very well be left until the plans for the canal were sufficiently developed to determine what relation the water supply would bear to that major product.

Some years prior to 1904 a project for a water supply for Panama made some progress until stopped by a revolution. The Juan Diaz River, some fifteen miles to the east of the city, had been selected as the source. This was an excellent stream, but by no means as readily available for rapid introduction as the Rio Grande River, adjacent to the Culebra Cut, some ten miles from the city. Availability being a controlling factor, the Rio Grande was adopted for Panama, and a complete system of water works and sewers was worked out and submitted to the Canal Commission. The work thereunder was authorized by the commission on August 9, 1904.

Actual construction work was subject to many annoying delays and was carried out under difficulties and amid some confusion. The general situation on the Isthmus at this period has been the subject of sharp criticism, much of which is easily explained at this time and at this distance from the actual work.

From the present viewpoint, it is apparent that a large part of the confusion attending the early Panama construction was due to the too prevalent American characteristic of hurry and rush without adequate preliminary preparation. The French Companies had failed in their effort to construct the canal. With the typical and commendatory American desire to make the canal a success, and break all speed records, the motto of "Now let the dirt fly" was impressed on those in charge. Immediate results in actual canal construction were demanded, irrespective of whether or not conditions were ripe for such work.

As a matter of fact, at the time the United States began operations there were about six hundred laborers, largely Jamaica negroes, actually at work upon the canal. There were, in addition, about five hundred more laborers scattered throughout the Isthmus who were possibly available to augment this force actually at work. A large percentage of this body of men was incapacitated to some degree by malaria fever, so that as a potential force for real work under American standards the numbers above given should be greatly decreased. Moreover, the entire plant and equipment turned over to the Americans was inadequate, out of repair, and generally inefficient and insufficient.

At the time water works construction was begun the Department of Health was organizing to put hospitals in shape, to cut down vegetation, to ditch, drain, and fumigate. The Building Department was getting ready to repair old houses, to make them habitable, and to build new ones. The Material and Supply Department was sorting old French stock, revamping the storehouses, and preparing to receive stores and deliver supplies. The Mechanical Department was putting the shops in order and repairing some of the machinery.

Transportation for all this work was practically limited to the Panama Railroad, which was barely able to handle ordinary trans-isthmian business, and entirely unable to cope with the additional operations incident to the canal work. Steamship docks were lacking, so that the necessary increased shipments of freight were almost out of the question.

Available for all work, there were perhaps a thousand or twelve hundred inefficient and incompetent Jamaica negroes. Each department needed more men, and yet no more men were wanted on the Isthmus until there was opportunity to house them, until water and food were ready, until there was provision to care for them if they should be sick. Each department depended upon and needed the other departments, and yet in a sense they were rivals.

With these handicaps and with the inherited incubus of disease and fevers not yet overcome, conditions governing work were necessarily somewhat primitive. Yet work on the Isthmus kept pace with the deliveries of supplies. To quote from a report of the Governor of the Canal Zone, under date of February 20, 1905: "It is now the middle of the dry season, water is scarce and very dear, and no increase in the supply can be expected from the new aqueduct for many months. The laying of the pipe is being done with expedition, and, in fact, a single cargo of water-pipe that has already been received was almost laid—every joint of it—before the last train-load pulled out from the railroad station. The pipe is sufficient in quantity to reach Pedro Miguel, but there now must be a wait of several weeks—and, I fear, months—before it can be completed."

Notwithstanding various obstacles, the water was finally introduced in the city of Panama, July 4, 1905. To quote from the report for that year of the Isthmian Canal Commission: "The water was turned on for the first time on July 4th of this year. It would be difficult to describe the gratification and gratitude of the inhabitants at the consummation of their long-deferred hope. Formal expression took the form of a special session of the Municipal Council and the adoption of resolutions of thanks and the appointment of a committee to present a copy thereof to the Governor of the Zone. The *Te Deum* was sung in the Cathedral, attended by President Amador and his cabinet and the principal officials of the commission on the Isthmus and of the government of the Canal Zone."

The water supplies for Colon and the various towns along the line of the Canal followed the introduction of the water system in Panama. As before stated, yellow fever was put under control, and its definite elimination was begun from the time of that introduction. As an important factor in the sanitation of the canal, the water supplies cannot be overlooked.

September 24, 1915.

Ultra-violet Radiation and the Eye. W. E. BURGE. (*Transactions Illuminating Engineering Society,* September 20–23, 1915.)—It has been recognized for some time that, unless protected by a glass globe, the radiation from a quartz mercury arc or from an iron arc or from any light source emitting large quantities of ultra-violet rays is harmful to the eye. In a general way it has been assumed that all radiation of shorter wave-lengths than 350 $\mu\mu$ is injurious to living tissues. An organ (*e.g.,* the eye) is composed of tissues—connective tissue, nervous tissue, etc. The tissues are composed of cells. Ultra-violet radiation kills living cells and tissues by changing the protoplasm of the cells in such a way that certain salts can combine with the protoplasm to form an insoluble compound or coagulum.

Cataract is an opacity of the crystalline lens. Many observers have demonstrated that it is impossible to produce an opacity of the lens or cataract in a normal living animal by exposure of its eye to ultra-violet radiation. Analyses of human cataractous lenses from America show a great increase in the salts of calcium and magnesium, and those from India show, in addition to these salts, silicates. Glass blowers who develop cataract form a relatively small proportion of those engaged in that occupation, and it is assumed that those who do develop it have a disturbed condition of nutrition, which expresses itself in an increase of those substances which can precipitate the portion of the lens acted upon by ultra-violet radiation.

An opacity of the lens or cataract can be produced in fish living in solutions of those salts, found to be greatly increased in human cataractous lenses, by exposing the eye of the fish to ultra-violet radiation. This cannot be done with fish living in tap-water.

THE CONDUCTIVITY AND VISCOSITY OF SOLUTIONS OF ELECTROLYTES IN FORMAMID.*

BY

P. B. DAVIS, W. S. PUTNAM, and HARRY C. JONES.

THE work of Jones and his collaborators in the field of non-aqueous solvents, and in mixtures of these solvents with one another, thus far included a comprehensive study of both the conductivity and viscosity of typical salts in methyl and ethyl alcohols, in acetone and in glycerol; as well as in binary and ternary mixtures of these solvents with one another and with water. A review of all this work is to be found in Publication of the Carnegie Institution of Washington No. 210, Chapter 7.

Because of the somewhat limited solubility of electrolytes in most organic solvents, the scope of this work has necessarily been somewhat limited in the case of the pure liquids themselves. This is especially true with acetone and the alcohols. Glycerol, however, notwithstanding its high viscosity, proved to be a remarkably good solvent.

Among the few remaining liquids suitable for such work, the one used in this investigation—formamid—is, perhaps, the most important.

The fact that it has been studied so little in the past must be attributed to the difficulties encountered in obtaining a product pure enough for conductivity purposes, and to its relatively high price.

PREVIOUS WORK IN FORMAMID.

Until quite recently no investigation of the physical chemical properties of this remarkable liquid had been made. A brief sketch of the recent work is given below.

In his preliminary paper on organic solvents, Walden mentions the marked similarity of formamid to water as compared with other liquids in its solvent action on inorganic salts, and in

---

* Communicated by Dr. Harry C. Jones.

This investigation was carried out with the aid of a grant from the Carnegie Institution of Washington to H. C. Jones, and will form a part of its Publication No. 230.

later papers he records some of its physical constants in comparison with other amids and with water, viz., the dielectric constant and association factors,[1] specific conductivity and molecular conductivity of the normal electrolyte $N(C_2H_5)_4I$[2] and the viscosity.[3] All of these constants were obtained with a product which, as will be shown later, was far from pure; although it may be pointed out that the first two constants are not appreciably affected by small changes in the purity of the solvent.

Turner and Merry,[4] in their work on the molecular composition of trivalent nitrogen compounds, pointed out that the high association factor of formamid is one of its most striking characteristics, and they observed its similarity to water. They noted also that the association of formamid diminishes more rapidly with rise in temperature than that of water, and suggested that the solvent power for salts was largely due to its high molecular complexity. Somewhat later, Walden,[5] in a study of the temperature coefficient K, for organic liquids in the Ramsay and Shields equation for molecular surface-tension, found that in the case of formamid the value was far below that for non-associated liquids (2.12), having only the value 0.594–0.710, and from these data obtained an association factor in close agreement with that as determined by Turner and Merry.[6]

Dunstan and Kassel,[7] while determining the fluidity of various binary mixtures, measured the viscosity of mixtures of formamid and *i*-amyl alcohol at both low and somewhat elevated temperatures, and noted a pronounced minimum in the fluidity curves at about 60 to 70 per cent. of formamid at both temperatures; and also a slight maximum at about 10 to 20 per cent. formamid for the lower temperature.

Rohler[8] studied the solvent properties of formamid for organic salts, and also the electrolysis of its solutions. He compared the density with that of water above the freezing-point and found no minimum, as in the case of the latter, but that the solvent expanded linearly with rise in temperature; the variation of the specific volume being represented by $V = 0.8674 \times (1 + .000742t)$.

---

[1] *Zeit. phys. Chem.*, 46, 145, 175 (1906).

[2] *Ibid.*, 54, 179 (1905).

[3] *Ibid.*, 55, 230 (1906).

[4] *Journ. Chem. Soc.*, 97, 2076 (1910).

[5] *Zeit. phys. Chem.*, 75, 555 (1910)

[6] *Loc cit.*

[7] *Zeit. phys. Chem.*, 76, 367 (1911).

[8] *Zeit. Elektrochem.*, 16, 420, (1910).

Rohler also found that, according to Faraday's law, copper dissolves in formamid at all dilutions, half as univalent and half as bivalent ions at the anode, and obtained a good separation of copper with a weak current; but with a stronger current the metal separated as a dark slime.

Similar results were obtained with lead, zinc, and tin. With all of these metals in air more metal dissolved at the anode than separated at the cathode. The electrolysis of nickel, cobalt, iron, aluminum, and magnesium salts yielded no appreciable amount of metal at the cathode.

Rohler also noted the formation of metallic formamidates, and also of crystalline double compounds, which will be considered in discussing the properties of formamid as compared with those of water.

In a quite recent paper Walden[9] gives an account of his cryoscopic work in this solvent. In his preliminary discussion he states as his reason for adopting the freezing-point rather than the conductivity method for measuring dissociations, that the high specific conductivity of the solvent (as measured by him) rendered it impossible to obtain accurate data by the latter method. However, as will be pointed out later, by our method of preparation, formamid with a specific conductivity comparable with that of water, may be obtained with a loss of material only one-third that experienced by Walden.

Walden determined the freezing-point constant of formamid, and gives the value 35.0 as the mean of six determinations using urea, acetic, ester, diethylsulphite, ethyl acetate, mesityl oxide, and nitraniline respectively as the solute.

He also studied the dissociation of a number of electrolytes, including salts and both strong and weak acids, and pointed out that all binary salts are strongly ionized at relatively high concentrations; the ionization increasing slowly to the limit $\alpha = 100$ as in water; the limit, however, being reached at a smaller dilution in formamid.

---

[9] *Bull. Imp. Acad. Sci.*, St. Petersburg (1911).

The same was found to hold for acids, except in the case of those where combination took place between solvent and solute, as in the case of some of the strong acids; the values found being smaller than those for water.

FORMAMID AS A SOLVENT.

Formamid is a clear, colorless, and somewhat viscous liquid, melting at about 18°, and boiling under atmospheric pressure with partial decomposition at 200° to 212°. It reacts neutral to litmus and is quite hygroscopic, undergoing a slow hydrolysis at ordinary temperature into ammonium formate.

This solvent is the most closely allied to water in its properties of all the organic solvents. The two are miscible in all proportions, neither being soluble to any extent in absolute ether, chloroform, benzol, hexane, etc.; nor do they dissolve appreciably the aromatic hydrocarbons, nitrobenzol, fats, oils, etc.

Further similarity may be traced in their solvent action on metallic salts, thus: in the cold, cobalt and nickel salts yield solutions in formamid, similarly colored with those in water; although in some instances the formamid solutions undergo change in color on warming, which is probably due to a predominance of the unionized salt, since formamid undergoes a much sharper decrease in association with rise in temperature than water.

As Walden has pointed out, the similarity between water and formamid is still more wide-reaching. Phosphorus and sulphur are practically equally insoluble in both, while iodine gives a brownish-yellow solution. Starch is also soluble in formamid with formation in concentrated solution of a jelly; and on addition of formamid solution of iodine the starch solution turns intensely blue. The color, however, is less permanent than in water, owing to the slow action of the iodine on the solvent. The fluorescent dyes also exhibit like phenomena in formamid and in water, this being particularly marked in the case of eosin.

Bruni and Manuelli [10] further show that just as water hydrolyzes the salts of weak bases, such as those of bismuth and antimony, forming unstable basic salts, formamid, by a process of amidolysis, may form basic salts of these same metals; and Rohler,[11] in extending this work, has isolated characteristic basic salts of copper, cobalt, nickel, and zinc. He also obtained amidates similar to hydrates, of which $PbCl_2.HCONH_2$ is an example; as well as metal formamidates having the general composition $Me(HNCOH)_2 2HCONH_2$, where Me may be either copper, nickel, cobalt, or zinc.

---

[10] *Zeit. Elektrochem.*, 11, 554 (1905).

[11] *Ibid.*, 16, 418 (1910).

In addition to the above, Rohler has noticed the formation of well-defined crystalline compounds of formamid with the halogen acids corresponding to the well-known mono-, di- and trihydrates.

As is now a well-established fact, the dielectric constant of the solvent is a measure of its own association, and therefore a measure of its dissociation power for electrolytes. Of the common solvents water has the highest dielectric constant, and is the best dissociant. Formamid, however, has a higher dielectric constant than water, as will be shown by referring to the following table of physical constants of the two solvents, and should therefore be a better dissociant, which will be pointed out in our discussion.

TABLE I.

	Water	Formamid
Molecular weight	18	45
Melting-point	0°	1.5–2.1 (Walden)
Boiling-point 760 mm.	100°	200–212
Density 0°/4°	.9999	1.151 (Walden, Davis)
Dielectric constant	81 (Drude) 25°	84 (Walden)
Association factor 30°	3.81 (Ramsay-Shield)	6.18 (Turner and Merry)
K—surface tension 20°–30°		0.65 (Turner and Merry)
Minimum specific conductivity	$4. \times 10^{-8}$	2.8×10^{-6} (Davis and Putnam)
Average specific conductivity working values	1.5×10^{-6}	2.7×10^{-5} (Davis and Putnam)
Viscosity 25°	0.00891 (Thorpe and Roger)	0.0324 (Davis)
Dissociation of $N(C_2H_5)_4I$ at V = 100	91%	93% (Walden) 98% (Davis and Putman)

PURIFICATION OF THE SOLVENT.

It might be well to note at the outset that neither a clean melting-point nor a constant boiling-point is a sufficient criterion for the purity of the solvent for conductivity purposes; since it has been found by ourselves and others that a constant boiling liquid such as formamid may be separated into fractions of widely different specific conductivities. That this is true is due no doubt in this particular case to the fact that minute quantities of the products of hydrolysis, such as would have no measurable effect on the apparent boiling-point of the liquid, on account of the high dissociating power of the formamid, produce a marked increase in its conductivity.

The chief criterion, therefore, in judging of the purity of the solvent used in this investigation was its specific conductivity. The material with which we started was obtained from Kahlbaum, and had a specific conductivity of about 674×10^{-5}, or about that of tap-water. Samples obtained from Bender and Hobein, Schuchardt, and from Hoffman and Kropff proved, from the conductivity standpoint, to be little or no better than the above.

As has already been pointed out, formamid is hygroscopic, forms a true solution with water, and subsequently undergoes slow hydrolysis into ammonium formate. The first problem, therefore, that presented itself, was the removal of any dissolved water not already acted on; and, second, the removal of the products of hydrolysis already present. The method of purification finally adopted made it necessary to design and construct suitable apparatus for distillation in comparatively high vacua.

A third problem presented itself in connection with the preservation and subsequent manipulation of the solvent and of solutions in it, in such a manner as to incur minimum exposure to moisture. In addition, the expense of the solvent made necessary the recovery of it with the least possible loss by decomposition from solutions of salts in this solvent.

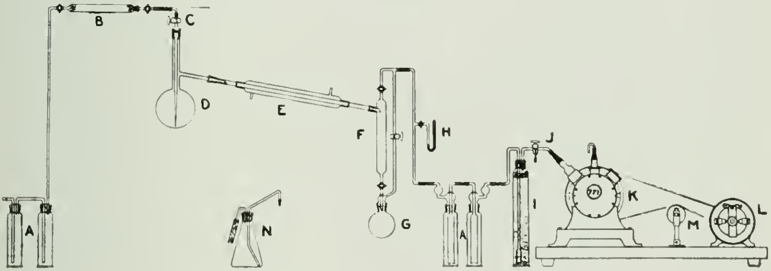
The removal of dissolved water was finally effected by the use of carefully dehydrated sodium sulphate. After testing a number of other dehydrating agents, such as magnesium sulphate, calcium chloride, sulphuric acid, *in vacuo,* etc., it was found that sodium sulphate produced a smaller loss of materials from combination with it than any of the other dehydrating agents studied.

Formamid was therefore allowed to stand for several weeks over anhydrous sodium sulphate, in carefully sealed, glass-stoppered bottles placed in a cool, dark room. An attempt was made to effect a preliminary purification of formamid by fractional crystallization, but the end product, after several fractionations, invariably showed a higher conductivity than the original substance. We were therefore forced to conclude, as were Freer and Sherman in preparing formamid, to study its sodium salts, that a properly conducted distillation process was the best one available.

The apparatus finally adopted for distillation is shown diagrammatically in Fig. 1; although by placing the various parts in parallel rows it was possible to mount the whole apparatus upon a desk space of only 2½ feet square, as is shown in the photograph Fig. 2.

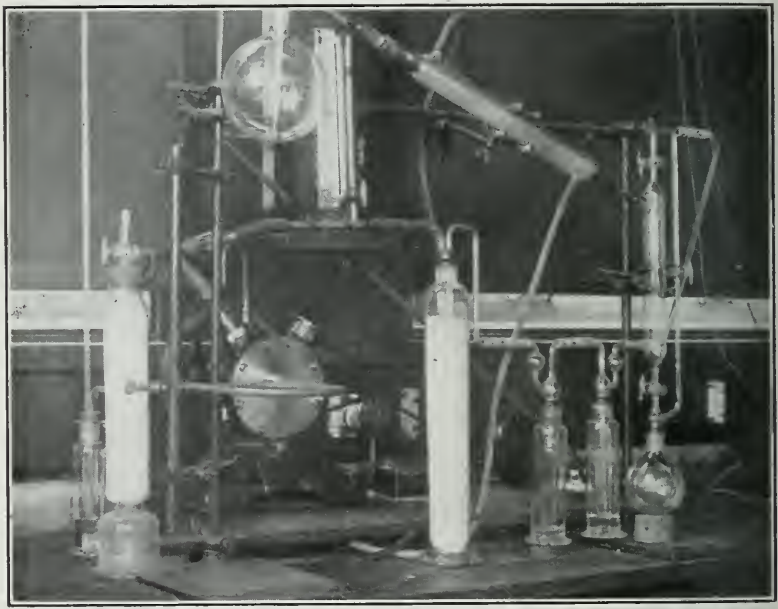
In this apparatus, with all the stop-cocks closed, a vacuum of 0.5 mm. was easily maintained by the Gaede pump (Fig. 1, *K*). This pump was mounted, together with a $^1/_{12}$-horse-power motor (Fig. 1, *L*), connecting rheostat (not shown), idler (Fig. 1, *M*), and switch, on a heavy maple-wood base, provided with carrying handles and rubber feet.

FIG. 1.



During the actual process of distillation, the vacuum rose to from 1.5 to 2.5 mm.; since, on account of the high viscosity of the liquid, it was necessary to keep a fairly rapid current of air flowing in through the stop-cock and drawn-out portion of the distillation head (Fig. 1, *E*), in order to keep the liquid agitated and prevent the violent bumping which usually attended distillation in a high vacuum. The drying of this current of air sufficiently, and the proper method of introducing it, proved to be one of the most serious difficulties encountered. The method finally adopted is shown in the figure. The air, before entering the distillation flask, passed through a soda line tower (not shown in the drawing, but appears on the left in Fig. 2), then through the two wash bottles (Fig. 1, *A*), and finally over phosphorus pentoxide contained in the long tube *B*, which was protected by two glass stop-cocks, the one sealed permanently into the tube and the other securely fastened with sealing wax in the left-hand tapered end of *B*. This joint made it possible to open *B*, in renewing the phosphorus pentoxide. From *B* the current of air passed into *C*, through a short rubber connection and a right-angle glass bend; the open end of which is connected with *C* by a rubber joint made air tight with rubber cement.

FIG. 2.



The distillation head *C* consisted of a short projecting tube, a well-ground stop-cock of large bore; the ground connection with the 750-cubic centimetre distilling flask *D*, and the long inner tube reaching to the bottom of the flask and drawn down to a capillary at the end, so as to cause the air to bubble in a fine stream through the liquid. Connection between the flask and the condenser was effected by a ground joint designed to prevent the liquid distilling over, from coming in contact with the stop-cock grease used in making the joint air-tight. The condenser was also ground into the Axtell receiver *F*, which is too well known to require further description, other than to state that the capacity of the barrel was about 100 cubic centimetres, and that of the small bulb 250 centimetres. The receiver allowed the removal of different fractions without interrupting the vacuum.

The receiver was connected with the pump *K*, through the gas wash bottles A^1, the soda lime tower *I*, and the three-way stop-cock *J*. One of the wash bottles was filled just to the upper level of the holes in the inner cylinder with sulphuric acid; the other being empty and serving as a trap in the case of back pressure. The construction of the wash bottles secured a maximum exposure of acid to the possible alkaline vapors (NH_3) without appreciable back pressure.

Liquid formamid was introduced into the flask at any time during the distillation without destroying the vacuum, by closing the stop-cock on *C*, temporarily disconnecting the air inlet, and attaching at the same point the flask and syphon *N*. On opening the stop-cock the diminished pressure in the flask drew in any liquid in *N*.

During the distillation the flask was immersed in a bath of hardened cottonseed oil (" Crisco "), into which the thermometer dipped. Ordinary rectified cottonseed oil was first used, but this was soon discontinued, since the oil quickly became rancid and offensive when heated. The " Crisco," however, remains sweet and untainted even after continued use. The temperature in the outer bath was maintained at from 10° to 15° higher than the boiling-point of the liquid at a given pressure; the usual temperature being 100° to 115°. In the apparatus used in the preliminary work a thermometer was sealed into the air inlet tube of *C*, with its bulb well down in the flask, and the boiling-point of the liquid observed; but this thermometer was subsequently discarded and the temperature controlled solely by the thermometer in the outer bath, so as to obtain about 100 cubic centimetres of distillate every 15 minutes.

As a rule, starting with Kahlbaum's so-called c.p. formamid, from three to four distillations yielded a product sufficiently pure for our purpose. The decrease in the conductivity with successive distillation is shown in the following table:

Specific Conductivity.

Original Material		674.0×10^{-5}
First distillation	First fraction	785.8×10^{-5}
	Second fraction	435.0×10^{-5}
	Third fraction	112.3×10^{-4}
Second distillation	First fraction	204.2×10^{-5}
	Second fraction	153.8×10^{-5}
	Third fraction	67.4×10^{-5}
Third distillation—first fraction		24.6×10^{-5}
		10.3×10^{-5}
		4.8×10^{-5}

While the end fraction in this case was sufficiently pure for use, a fourth distillation yielded a product with the conductivity of about $3–4\times10^{5}$; although the exact minimum conductivity of this solvent has thus far not been ascertained, we have obtained small lots with a specific conductivity of $2.8\times10,^{-6}$ or from two to three times the value for the conductivity water used in this laboratory. Walden used in his work a product with a conductivity of 7.5×10^{-4}, but obtained a small fraction of about 10 per cent. of the original material, with a conductivity of 4.7×10^{-5}. Our solvent was from 35 to 40 per cent. of the original volume with a maximum specific conductivity of 4.8×10^{-5}, with a minimum of 1.37×10^{-5} and an average of 2.7×10^{-5}.

SALTS.

On account of the instability of the solvent formamid in the presence of moisture, the salts used in this investigation were all dehydrated with special care at the highest temperature which it was possible to use for these substances.

SOLUTIONS.

The more concentrated solutions in formamid were made up by direct weighing; the more dilute by diluting the more concentrated. This operation was much facilitated by the use of two burettes holding 50 and 10 centimetres respectively; the one being employed for the solvent, the other for the one-tenth normal solution. Each burette was connected with the reservoir containing the solvent or the solution by a siphon provided with a glass stop-cock; and access of moisture being prevented by calcium chloride tubes connected with both the burettes and the reservoirs.

The solvent was kept until required in half-litre glass-stoppered Erlenmeyer flasks, and the solutions when made up were preserved in 35 c.c. flasks of similar design, which were sealed with rubber cement.

On account of the high price of the solvent, only 25 cubic centimetres of each solution was prepared; this amount serving both for conductivity and viscosity measurements. All operations in preparing the solutions were carried out at 20°.

CONDUCTIVITY APPARATUS.

The conductivity apparatus used in this investigation was identical with that employed in our earlier work on binary and ternary mixtures of water, acetone, and glycerol; the method of obtaining duplicate readings and other details being exactly the same as in the earlier work, with the exception of the use of a rocking commutator with mercury contact, instead of the two-blade, double-throw switch used in reading both ends of the bridge; the object being to eliminate as nearly as possible all external resistance.

The conductivity cells were also of the type recently employed in this laboratory for work with non-aqueous solvents, and were carefully standardized at regular intervals.

VISCOSITY APPARATUS.

The apparatus used in this work was essentially the same as in our earlier investigations. We have designed and used an improved support for the viscometers, which is particularly well adapted to our new thermostat. A new pyknometer * has also been devised, which has proved to have advantages over the older form.

THERMOSTATS.

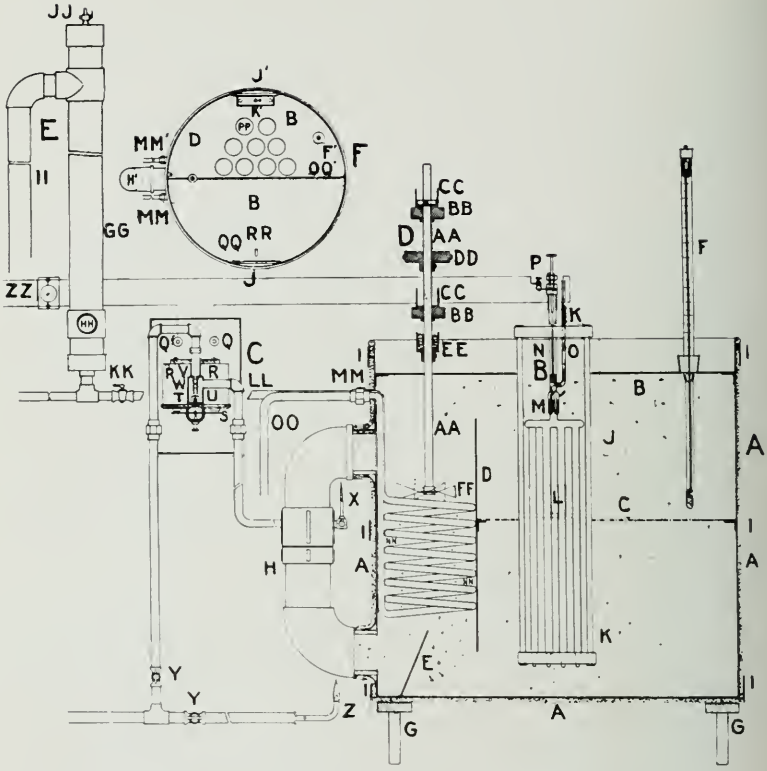
The new form of constant temperature bath for conductivity and viscosity investigations, which has already been fully described in Chapter 6 of the Publication of the Carnegie Institution of Washington, No. 210, has already met with such approval that by request it is here described in some detail.

These thermostats are substantially constructed of copper and use gas for maintaining constant temperature; the heat being applied directly to a heavy galvanized iron pipe (Fig. 3, *A–H*), outside the bath, through which a part of the water is kept circulating by means of the propellers (*FF*). This mixes with the remainder of the water in the space enclosed by the cooling coils (*NN*), and the diaphragm *I*. By this means a very even distribu-

---

* *Jour. Am. Chem. Soc.*, 37, 1199 (1915).

Fig. 3.



Constant temperature apparatus used in conductivity and viscosity investigation.

A. Sixty-litre Bath of 20-ounce Copper:

(A) Asbestos insulation; (B) sheet-brass cover; (C) woven wire grid; (D) semicircular diaphragm; (E) deflector to divert part of the water into the heater pipes; (F) thermometer; (G) tripod; (H) galvanized iron heater pipes attached to bath with 1½-inch brass nipples; (I) brass bands supporting insulation; (J) outline of windows shown also in *F*.

B. Thermostat:

(K) Holder; (L) toluol reservoir tubes with ¼-mm. walls. (M) expansion chamber partially filled with mercury; (N) 1.5-mm. capillary; (O) side arm with sealed-in platinum contact.

C. Gas Flow Regulator:

(Based on "steel block" devised by E. E. Reid, *Amer. Chem. Journ.*, 41, 151, and improved by others.)

(Q) Binding posts to coils; (R) magnet coils; (S) armature; (T) steel valve-chamber; (U) plunger, with rubber washer and mercury seal, working against end of gas-supply pipe (V) and wire to armature (S); (W) needle valve to regulate size of pilot flame (shown as dotted circle); (X) microburner with needle valve; (Y) gas-cocks regulating supply to relay and rough heater; (Z) high-voltage lamp spanning spark-gap of thermostat.

D. Stirring Mechanism:

(AA) Shaft; (BB)-shaped bracket supporting (CC) oil cups and journals; (DD) pulley with oil trap filled with waste; (EE) oil trap; (FF) six-bladed 3½-inch propeller.

E. Cooling System:

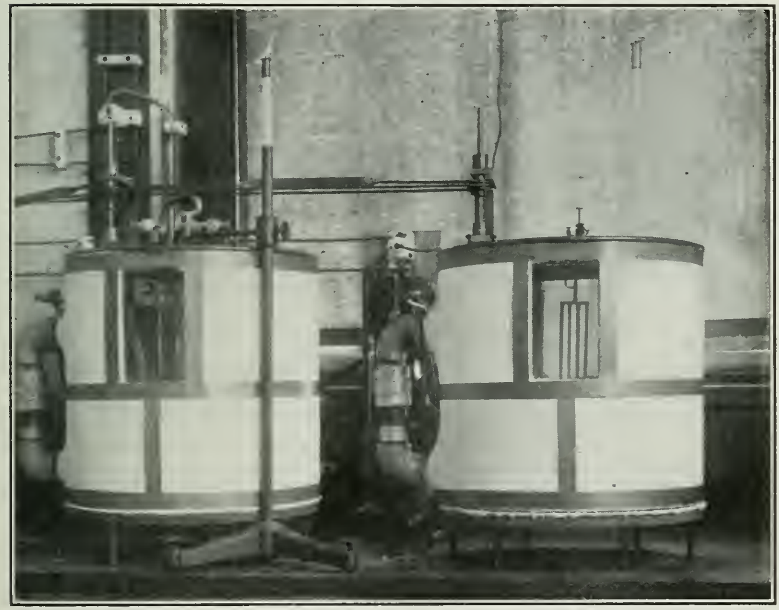
(GG) Standpipe; (HH) supply; (II) overflow; (JJ) pet-cock in cap; (KK) regulating valve to coils; (LL) inlet pipe to coils; (MM) interchangeable unions (here ice- or hot-water coils may be inserted for very low or high temperatures); (NN) cooling coils; (OO) waste pipe.

F. Diagram of Top (smaller scale):

(B), (D), (F), (H), (J), and (K) the same as in *A*; (MM) same as in *E*; (PP) apertures in cover for conductivity cells; (QQ) lugs supporting cover; (RR) handle to removable section of cover.

tion of heat is obtained, and because of the large heat capacity of the bath itself, these thermostats are insensible to other than marked changes in room temperature. The improved toluol regulator (Fig. 1, *B*), mentioned in our publication on conductivity and viscosity in ternary mixtures, and described in detail elsewhere,[12] was used to operate the relays controlling the gas-supply to the micro-burners of the thermostats. The gas valve shown in the illustration is an improvement made by others on the steel block devised by E. E. Reid, and was used throughout the greater part of this work. Subsequently, however, a new type of valve was devised here for eliminating the expensive telegraph relay and the mercury seal of the plunger *U*. Preliminary tests have shown this valve to have decided advantages over the former thermostats; and should it prove satisfactory a complete discussion will appear later. There are at present in this laboratory seven

FIG. 4.



---

[12] *Journ. Amer. Chem. Soc.*, 37, 1198 (1915).

such thermostats in use, and they are capable of maintaining temperature uniform to within 0.01° at 15° and 35°, and to within 0.003 to 0.005 at 25°. The thermostats used in this laboratory are all driven by a single $\frac{1}{12}$-horse-power, direct-current motor. The complete baths are shown in Fig. 4.

Both conductivity and viscosity measurements were made at 15°, 25°, and 35°; the data are tabulated in the usual manner, tables of constants and the use of a calculating machine greatly facilitating the calculations.

TABLE II.

Comparison of the Various Solvents.

Solvent	Dielectric constant	Association factor	Viscosity at 25°
HCN	95		
$HCONH_2$	94	6.18	0.0326
H_2O	81.7	3.81	0.0089
CH_3OH	32.5	3.43	0.0056
C_2H_5OH	21.7	2.74	0.0111
$C_3H_5(OH)_3$	16.5	1.80	5.854
$CH_3-CO-CH_3$	20.7	1.26	0.0035

TABLE III.

Sodium Bromide in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity 15°	25°	35°	Dissociation 15°	25°	35°
2	11.83	15.53	19.76	62.1	63.1	63.4
4	13.80	18.01	22.82	72.4	73.2	73.6
10	16.20	21.09	26.64	85.0	85.7	86.0
50	17.46	22.62	28.55	91.6	91.9	92.1
200	18.79	24.36	30.59	98.6	98.9	98.7
400	19.06	24.62	30.99	100.0	100.0	100.0
*K	1.53×10^{-5}	1.99×10^{-5}	2.46×10^{-5}			

*K is the specific conductivity of the solvent

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent. 15°–25°	25°–35°	Conductivity units 15°–25°	25°–35°
2	0.0313	0.0272	0.370	0.423
4	0.0305	0.0267	0.421	0.481
10	0.0302	0.0263	0.489	0.555
50	0.0296	0.0262	0.516	0.593
200	0.0296	0.0256	0.557	0.623
400	0.0292	0.0259	0.0556	0 637

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
2	0.05578	0.04081	0.03120	17.93	24.50	32.05
4	0.04883	0.03678	0.02837	20.48	27.19	35.25
10	0.04523	0.03413	0.02666	22.11	29.30	37.51
Solv.	0.04274	0.03194	0.02511	23.40	31.31	39.83

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
2	0.0367	0.0308
4	0.0328	0.0296
10	0.0325	0.0280
Solv.	0.0338	0.0272

TABLE IV.

Sodium Iodide in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity 15°	25°	35°	Dissociation 15°	25°	35°
2	11.92	15.71	20.01	64.7	65.6	66.1
4	14.17	18.57	23.59	76.9	77.5	78.0
10	15.91	20.67	26.05	86.3	86.3	86.1
50	17.17	22.33	28.17	93.2	93.2	93.1
200	18.27	23.80	29.98	99.1	99.3	99.1
400	18.43	23.96	30.25	100.0	100.0	100.0
K	2.23×10^{-5}	2.83×10^{-5}	3.48×10^{-5}			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent. 15°–25°	25°–35°	Conductivity units 15°–25°	25°–35°
2	0.0318	0.0274	0.379	0.430
4	0.0311	0.0270	0.440	0.502
10	0.0299	0.0260	0.476	0.538
50	0.0301	0.0262	0.516	0.584
200	0.0303	0.0260	0.553	0.618
400	0.0300	0.0263	0.553	0.629

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
2	0.05425	0.03997	0.03065	18.43	25.02	32.63
4	0.04822	0.03640	0.02800	20.74	27.47	35.71
10	0.04532	0.03381	0.02653	22.07	29.58	37.69
Solv.	0.04307	0.03302	0.02570	23.22	30.29	38.91

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15 –25°	25 –35°
2	0.0357	0.0304
4	0.0325	0.0300
10	0.0340	0.0274
Solv.	0.0304	0.0285

TABLE V.

Sodium Chromate in Formamid.

MOLECULAR CONDUCTIVITY.

V	Molecular conductivity 15°	25°	35°
10	24.57	33.66	42.66
50	31.46	41.48	52.18
200	34.34	44.82	56.38
400	39.00	50.79	.....
800	42.64	55.07	69.16
1600	72.06	93.51	116.44
K	1.30×10^{-5}	1.65×10^{-5}	2.03×10^{-5}

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent. 15°–25°	Per cent. 25°–35°	Conductivity units 15°–25°	Conductivity units 25°–35°
10	0.0316	0.0267	0.809	0.900
50	0.0319	0.0258	1.002	1.070
200	0.0305	0.0258	1.048	1.156
400	0.0302	......	1.179	.....
800	0.0292	0.0256	1.243	1.409
1600	0.0298	0.0245	2.145	2.293

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
10	0.04966	0.03633		20.14	27.30	
Solv.	0.04301	0.03221		23.25	31.05	

TABLE VI.

Potassium Chloride in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity 15°	25°	35°	Dissociation 15°	25°	35°
2	14.12	18.25	22.94	67.9	68.3	68.7
4	16.15	20.84	26.13	77.6	78.0	78.3
10	18.06	23.27	28.99	86.8	87.1	86.8
50	19.27	24.94	31.12	92.6	93.3	93.2
200	20.66	26.60	33.10	99.3	99.5	99.1
400	20.80	26.73	33.39	100.0	100.0	100.0
K	2.94×10^{-5}	3.75×10^{-5}	4.69×10^{-5}			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent. 15°–25°	Per cent. 25°–35°	Conductivity units 15°–25°	Conductivity units 25°–35°
2	0.0292	0.0257	0.413	0.469
4	0.0290	0.0252	0.469	0.529
10	0.0288	0.0246	0.521	0.572
50	0.0294	0.0248	0.567	0.618
200	0.0288	0.0244	0.594	0.650
400	0.0285	0.0249	0.593	0.666

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
2	0.05251	0.03922	0.03000	19.04	25.50	33.33
4	0.04724	0.03572	0.02794	21.17	28.00	35.79
10	0.04457	0.03386	0.02642	21.94	29.53	37.85
Solv.	0.04304	0.03256	0.02542	23.23	30.71	39.34

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
2	0.0339	0.0307
4	0.0323	0.0278
10	0.0338	0.0282
Solv.	0.0322	0.0281

TABLE VII.

Potassium Iodide in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

	Molecular conductivity			Dissociation		
V	15°	25°	36°	15°	25°	35°
2	14.42	18.67	23.29	70.7	71.0	71.0
4	16.32	21.05	26.34	80.0	80.1	80.3
10	18.23	23.45	29.21	89.4	89.2	89.0
50	19.25	24.87	31.03	94.4	94.6	94.5
200	20.39	26.28	32.81	100.0	100.0	100.0
400	20.26	26.29	32.82			
K	2.23×10^{-5}	2.83×10^{-5}	3.48×10^{-5}			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

	Per cent.		Conductivity units	
V	15°–25°	25°–35°	15°–25°	25°–35°
2	0.0295	0.0247	0.425	0.462
4	0.0290	0.0251	0.473	0.529
10	0.0286	0.0246	0.522	0.576
50	0.0292	0.0248	0.562	0.616
200	0.0289	0.0248	0.589	0.653

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
2	0.04982	0.03710	0.02884	20.07	......	34.67
4	0.04631	0.03525	0.02716	21.59	28.37	36.81
10	0.04418	0.03353	0.02629	22.64	29.82	38.04
Solv.	0.04307	0.03302	0.02570	23.22	30.29	38.91

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
2	0.0343	0.0286
4	0.0314	0.0298
10	0.0318	0.0274
Solv.	0.0304	0.272

TABLE VIII.

Potassium Sulphocyanate in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity 15°	25°	35°	Dissociation 15°	25°	35°
2	15.15	19.10	24.28	70.0	69.2	70.4
4	17.42	22.31	27.87	80.6	80.8	80.8
10	19.04	24.38	30.35	88.0	88.3	88.0
50	20.02	25.61	32.16	92.6	92.8	93.3
200	21.21	27.19	33.89	98.1	98.5	98.3
400	21.62	27.60	34.47	100.0	100.0	100.0
K	1.07×10^{-5}	1.37×10^{-5}	1.69×10^{-5}			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent. 15°–25°	25°–35°	Conductivity units 15°–25°	25°–35°
2	0.0261	0.0271	0.395	0.518
4	0.0281	0.0249	0.489	0.556
10	0.0280	0.0245	0.534	0.597
50	0.0279	0.0256	0.558	0.655
200	0.0282	0.0246	0.598	0.670
400	0.0277	0.0249	0.598	0.687

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
2	0.04891	0.03657	0.02838	20.45	27.35	35.24
4	0.04585	0.03473	0.02713	21.81	28.79	36.86
10	0.04369	0.03280	0.02574	22.89	30.49	38.85
Solv.	0.04294	0.03258	0.02554	23.29	30.69	39.15

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
2	0.0337	0.0287
4	0.0320	0.0280
10	0.0332	0.0274
Solv.	0.0314	0.0276

TABLE IX.

Ammonium Bromide in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity 15°	25°	35°	Dissociation 15°	25°	35°
2	16.31	20.85	25.79	70.6	70.6	70.0
4	18.21	23.31	28.88	78.8	78.9	78.3
10	20.57	26.21	32.53	89.0	88.7	88.3
50	21.82	27.94	34.82	94.4	94.6	94.5
200	22.63	28.83	35.93	97.9	97.6	97.5
400	23.11	29.54	36.86	100.0	100.0	100.0
K	2.94×10^{-5}	3.76×10^{-5}	4.67×10^{-5}			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent.		Conductivity units	
	15°–25°	25°–35°	15°–25°	25°–35°
2	0.0278	0.0237	0.454	0.494
4	0.0280	0.0247	0.510	0.557
10	0.0274	0.0241	0.564	0.632
50	0.0280	0.0246	0.612	0.688
200	0.0274	0.0246	0.620	0.710
400	0.0278	0.0248	0.643	0.732

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
2	0.04795	0.03607	0.02776	20.86	27.73	36.02
4	0.04550	0.03455	0.02680	21.98	28.94	37.31
10	0.04399	0.03273	0.02635	22.73	30.55	37.95
S.	0.04304	0.03256	0.02542	23.23	30.71	39.34

TEMPERATURE COEFFICIENTS.

V	15°–25°	25°–35°
2	0.0330	0.0299
4	0.0317	0.0289
10	......	......
S.	0.0322	0.0281

TABLE X.

Ammonium Iodide in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity			Dissociation		
	15°	25°	35°	15°	25°	35°
2	16.90	21.70	26.80	73.6	73.1	72.5
4	18.78	24.06	29.88	81.8	81.0	80.8
10	20.48	26.32	32.44	89.2	88.6	87.7
50	21.31	27.39	33.92	92.8	92.3	91.2
100	22.20	28.40	35.40	96.7	95.7	95.8
400	22.96	29.69	36.97	100.0	100.0	100.0
K	3.68×10^{-5}	4.71×10^{-5}	5.87×10^{-5}			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent.		Conductivity units	
	15°–25	25°–35	15°–25	25°–35
2	0.0284	0.0281	0.480	0.610
4	0.0281	0.0240	0.528	0.582
10	0.0285	0.0233	0.584	0.612
50	0.0285	0.0238	0.608	0.653
100	0.0279	0.0246	0.620	0.700
400	0.0293	0.0245	0.673	0.728

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
2	0.05091	0.03856	0.03007	19.64	25.93	33.26
4	0.04571	0.03417	0.02669	21.88	29.27	37.47
10	0.04367	0.03311	0.02607	22.90	30.20	38.36
Solv.	0.04201	0.03207	0.02496	23.80	31.18	40.06

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
2	0.0320	0.0282
4	0.0292	0.0280
10	0.0319	0.0270
S.	0.0310	0.0285

TABLE XI.

Tetramethyl Ammonium Chloride in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity 15°	25°	35°	Dissociation 15°	25°	35°
2	14.62	18.72	23.38	68.6	68.5	68.1
4	16.92	21.80	27.27	79.4	79.7	79.4
10	18.37	23.65	29.32	86.2	86.5	85.4
50	19.64	25.32	31.65	92.1	92.6	92.1
200	21.19	27.34	34.11	99.5	100.0	99.3
400	21.30	27.34	34.35	100.0	100.0	100.0
K	1.53×10^{-5}	1.99×10^{-5}	2.46×10^{-5}			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent. 15°–25	25°–35	Conductivity units 15°–25–	25°–35
2	0.0280	0.0249	0.410	0.466
4	0.0288	0.0251	0.488	0.547
10	0.0287	0.0240	0.528	0.567
50	0.0289	0.0250	0.568	0.633
200	0.0290	0.0248	0.615	0.677
400	0.0283	0.0256	0.604	0.701

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
2	0.04775	0.03578	0.02791	20.94	27.95	35.83
4	0.04503	0.03427	0.02679	22.21	29.18	37.33
10	0.04394	0.03313	0.02601	22.76	30.18	38.45
Solv.	0.04274	0.03194	0.02511	23.40	31.31	39.83

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
2	0.0335	0.0282
4	0.0314	0.0279
10	0.0326	0.0274
Solv.	0.0338	0.0272

TABLE XII.

Tetraethylammonium Iodide in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity 15°	25°	35°	Dissociation 15°	25°	
2	11.78	15.42	19.47	62.6	63.5	64.0
4	13.86	18.10	22.78	73.7	74.5	74.0
10	15.74	20.31	25.31	83.7	83.6	83.2
50	17.60	22.69	28.47	93.6	93.5	93.6
100	18.45	23.79	29.85	98.1	98.0	98.1
200	18.81	24.28	30.43	100.0	100.0	100.0
K	2.47×10^{-5}	3.17×10^{-5}	3.94×10^{-5}			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent. 15°–25°	25°–35°	Conductivity units 15°–25°	25°–35°
2	0.0309	0.0262	0.364	0.405
4	0.0306	0.0259	0.424	0.468
10	0.0290	0.0246	0.457	0.500
50	0.0298	0.0255	0.509	0.578
100	0.0289	0.0255	0.534	0.606
200	0.0291	0.0253	0.547	0.615

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
2	0.04879	0.03618	0.02802	20.50	27.64	35.68
4	0.04573	0.03486	0.02687	21.87	28.69	37.22
10	0.04431	0.03336	0.02607	22.57	29.98	38.36
Solv.	0.04284	0.03256	0.02561	23.34	30.71	39.05

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
2	0.0349	0.0291
4	0.0312	0.0297
10	0.0328	0.0280
Solv.	0.0316	0.0271

TABLE XIII.

Rubidium Chloride in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity 15°	25°	35°	Dissociation 15°	25°	35°
2	14.28	18.46	23.10	67.7	68.1	68.6
4	16.31	21.00	26.17	77.3	77.5	78.0
10	18.77	24.09	30.10	89.0	88.9	89.3
50	19.84	25.54	31.82	94.1	94.3	94.4
100	20.59	26.49	33.03	97.6	97.8	98.0
200	21.09	27.08	33.69	100.0	100.0	100.0
K	2.47×10^{-5}	3.17×10^{-5}	3.94×10^{-5}			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent.		Conductivity units	
	15°–25°	25°–35°	15°–25°	25°–35°
2	0.0292	0.0251	0.418	0.464
4	0.0288	0.0251	0.469	0.527
10	0.0283	0.0249	0.532	0.601
50	0.0287	0.0246	0.570	0.628
100	0.0287	0.0247	0.590	0.654
200	0.0284	0.0244	0.599	0.661

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
2	0.05246	0.03869	0.02961	19.06	25.85	33.77
4	0.04773	0.03606	0.02778	20.95	27.73	36.00
10	0.04486	0.03396	0.2623	22.29	29.45	38.12
Solv.	0.04284	0.03256	0.2561	23.34	30.71	39.05

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
2	0.0356	0.0308
4	0.0324	0.0298
10	0.0321	0.0295
S.	0.0316	0.0271

Table XIV.

Rubidium Bromide in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity			Dissociation		
	15°	25°	35°	15°	25°	35°
4	16.36	21.26	26.52	79.8	81.1	81.2
10	18.47	23.79	29.63	90.1	90.8	90.7
50	20.49	26.21	32.68	100.0	100.0	100.0
100	20.36	26.27	32.71			
K	4.79×10^{-5}	6.07×10^{-5}	7.62×10^{-5}			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent.		Conductivity units	
	15°–25	25°–35	15°–25	25°–35
4	0.0300	0.0247	0.490	0.526
10	0.0286	0.0245	0.532	0.584
50	0.0279	0.0247	0.572	0.647

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
2	Solution supersaturated at 25°					
4	0.04661	0.03501	0.02717	21.46	28.56	36.81
10	0.04462	0.03394	0.02648	22.41	29.46	37.76
Solv.	0.04312	0.03260	0.02564	23.19	30.68	39.00

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
4	0.0331	0.0289
10	0.0315	0.0282
S.	0.0323	0.0271

TABLE XV.

Rubidium Iodide in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

	Molecular conductivity			Dissociation		
V	15°	25°	35°	15°	25°	35°
2	14.73	19.01	23.78	72.4	72.0	72.2
4	16.87	21.71	27.21	82.9	82.2	82.6
10	18.60	24.00	29.83	91.4	90.9	90.5
50	19.59	25.27	31.49	96.3	95.7	95.6
100	20.23	26.06	32.62	99.5	98.7	98.7
200	20.34	26.41	32.95	100.0	100.0	100.0
K	3.68×10^{-5}	4.71×10^{-5}	5.87×10^{-5}			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

	Per cent.		Conductivity units	
V	15°–25°	25°–35°	15°–25°	25°–35°
2	0.0290	0.0251	0.428	0.477
4	0.0287	0.0253	0.484	0.550
10	0.0290	0.0243	0.540	0.583
50	0.0290	0.0246	0.568	0.622
100	0.0288	0.0248	0.568	0.646
200	0.0298	0.0248	0.607	0.654

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
2	0.04945	0.03516	0.02865	20.22	27.66	34.90
4	0.04643	0.03503	0.02737	21.54	28.55	36.54
10	0.04432	0.03348	0.02634	22.56	29.87	37.97
S.	0.04201	0.03207	0.02496	23.80	31.18	40.06

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
2	0.0368	0.0265
4	0.0325	0.0280
10	0.0324	0.0271
S.	0.0310	0.0285

TABLE XVI.

Rubidium Nitrate in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

	Molecular conductivity			Dissociation		
V	15°	25°	35°	15°	25°	35°
4	16.20	20.79	25.85	77.7	77.6	77.6
10	18.85	24.07	30.00	90.4	89.8	90.1
50	20.22	25.97	32.23	97.0	96.9	96.8
100	20.85	26.80	33.31	100.0	100.0	100.0
200	20.76	26.68	33.02			
K	2.47×10^{-5}	3.17×10^{-5}	3.94×10^{-5}			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent.		Conductivity units	
	15°–25	25°–35	15°–25	25°–35
4	0.0283	0.0243	0.459	0.506
10	0.0277	0.0246	0.522	0.593
50	0.0284	0.0241	0.575	0.626
100	0.0285	0.0243	0.595	0.651

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
4	0.04586	0.03430	0.02673	21.81	29.16	37.41
10	0.04417	0.03346	0.02622	22.64	29.89	38.15
Solv.	0.04284	0.03256	0.02561	23.34	30.71	39.05

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
4	0.0337	0.0283
10	0.0320	0.0276
Solv.	0.0316	0.0271

Table XVII.

Cæsium Chloride in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity			Dissociation		
	15°	25°	35°	15°	25°	35°
4	16.83	21.69	27.15	78.6	78.8	78.7
10	18.75	24.09	30.03	87.6	87.5	87.1
200	21.40	27.54	34.49	100.0	100.0	100.0
400	21.06	27.15	34.11			
K	1.34×10^{-5}	1.72×10^{-5}	2.10×10^{-5}			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent.		Conductivity units	
	15°–25°	25°–35°	15°–25°	25°–35°
4	0.0289	0.0252	0.486	0.546
10	0.0285	0.0247	0.534	0.594
200	0.0287	0.0252	0.614	0.695
400	0.0289	0.0256	0.609	0.696

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
4	0.04735	0.03578	0.02789	21.12	27.95	35.86
10	0.04481	0.03395	0.02654	22.32	29.46	37.68
Solv.	0.04317	0.03245	....	23.16	30.18	....

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
4	0.0323	0.0281
10	0.0320	0.0279
Solv.	......	

TABLE XVIII.

Cæsium Nitrate in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity 15°	25°	35°	Dissociation 15°	25°	35°
4	17.00	21.79	27.10	78.2	78.1	78.3
10	18.90	24.23	29.92	86.9	86.8	86.4
100	21.36	27.42	33.99	98.2	98.3	98.2
200	21.75	27.90	34.61	100.0	100.0	100.0
400	21.59	27.64	34.43			
K	1.34×10^{-5}	1.72×10^{-5}	2.10×10^{-5}			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent. 15°–25°	25°–35°	Conductivity units 15°–25°	25°–35°
4	0.0282	0.0244	0.479	0.531
10	0.0282	0.0235	0.533	0.569
100	0.0284	0.0240	0.606	0.657
200	0.0283	0.0241	0.615	0.671
400	0.0280	0.0246	0.605	0.679

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
4	0.04614	0.03478	0.02725	21.67	28.75	36.70
10	0.04456	0.03362	0.02632	22.44	29.74	37.90
Solv.	0.04317	0.03245	....	23.16	30.81	.....

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
4	0.0327	0.0276
10	0.0325	0.0277
Solv.	......	......

TABLE XIX.

Lithium Nitrate in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity 15°	25°	35°	Dissociation 15°	25°	35°
2	12.16	15.57	.....	66.0	65.8	....
4	14.10	18.07	.....	76.5	76.4	....
10	16.11	20.58	25.54	87.5	87.0	86.9
50	17.38	22.29	27.68	94.4	94.2	94.1
200	18.42	23.66	29.34	100.0	100.0	99.8
400	18.23	23.63	29.40	.....	.....	100.0
K						

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

	Per cent.		Conductivity units	
V	15°–25°	25°–35°	15°–25°	25°–35°
2	0.0280	......	0.341	.....
4	0.0281	......	0.397	.....
10	0.0277	0.0241	0.447	0.496
50	0.0283	0.0242	0.491	0.539
200	0.0284	0.0240	0.524	0.568
400	0.0296	0.0244	0.540	0.577

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	ς 35°	φ 15°	φ 25°	φ 35°
2	0.05191	0.03873	0.03019	19.26	25.82	33.12
4	0.04720	0.03571	0.02786	21.19	28.00	35.89
10	0.04460	0.03157	0.02646	22.42	31.68	37.79
Solv.	0.04272	0.03196	0.02503	23.41	31.29	39.95

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
2	0.0340	0.0283
4	0.0321	0.0282
10	......	......
Solv.	0.0337	0.0277

TABLE XX.

Barium Chloride in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

	Molecular conductivity			Dissociation		
V	15°	25°	35°	15°	25°	35°
10	30.58	40.00	50.12	70.3	71.6	70.1
50	38.06	49.43	61.90	87.5	88.5	86.6
200	40.38	52.48	65.93	92.9	93.9	92.2
800	43.45	55.82	70.38	99.9	99.9	98.5
1600	43.48	55.86	71.48	100.0	100.0	100.0
K	1.58×10^{-5}	2.02×10^{-5}	2.45×10^{-5}			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

	Per cent.		Conductivity units	
V	15°–25°	25°–35°	15°–25°	25°–35°
10	0.0308	0.0253	0.942	1.012
50	0.0299	0.0234	1.137	1.157
200	0.0300	0.0256	1.210	1.345
800	0.0285	0.0261	1.237	1.456
1600	0.0285	0.0280	1.238	1.562

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
10	0.04941	0.03702	0.02878	20.24	27.01	34.75
Solv.	0.04301	0.03221	0.02510	23.25	31.05	39.84

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
10	0.0322	0.0280
Solv.	0.0335	0.0283

TABLE XXI.

Mercuric Chloride in Formamid.

MOLECULAR CONDUCTIVITY.

V	Molecular conductivity 15°	25°	35°
4	0.43	0.59	0.83
10	0.63	0.87	1.27
50	1.09	1.56	2.22
200	1.74	2.53	3.68
400	2.73	4.15	5.82
1000	....	134.49	....
1600	....	101.13	....
3200	....	75.35	....
K	1.30×10^{-5}	1.65×10^{-5}	2.03×10^{-5}

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent. 15°–25°	25°–35°	Conductivity units 15°–25°	25°–35°
4	0.0372	0.0407	0.016	0.024
10	0.0381	0.0460	0.024	0.040
50	0.0431	0.0423	0.047	0.066
200	0.0437	0.0455	0.076	0.115
400	0.0520	0.0402	0.142	0.167

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
4	0.04688	0.03527	....	21.33	28.35	.....
10	0.04496	0.03376	....	22.25	29.62	.....
Solv.	0.04301	0.03221	0.02510	23.25	31.05	39.84

TABLE XXII.

Cobalt Bromide in Formamid.

MOLECULAR CONDUCTIVITY AND DISSOCIATION.

V	Molecular conductivity 15°	25°	35°	Dissociation 15°	25°	35°
10	27.11	35.35	44.30	60.9	61.4	60.7
50	34.70	45.01	56.56	78.0	78.1	77.5
200	39.00	50.34	.....	87.7	87.4	....
800	44.48	57.60	72.95	100.0	100.0	100.0
1600	41.83	53.96	68.70			

TEMPERATURE COEFFICIENTS OF CONDUCTIVITY.

V	Per cent.		Conductivity units	
	15°–25°	25°–35°	15°–25°	25°–35°
10	0.0304	0.0253	0.825	0.895
50	0.0297	0.0257	1.031	1.155
200	0.0291	......	1.134	.....
800	0.0295	0.0266	1.312	1.535
1600	0.0290	0.0273	1.213	1.474

VISCOSITY AND FLUIDITY.

V	η 15°	η 25°	η 35°	φ 15°	φ 25°	φ 35°
10	0.04892	0.03699	0.02867	20.44	27.03	34.88
Solv.	0.04301	0.03221	0.02510	23.25	31.05	39.84

TEMPERATURE COEFFICIENTS OF FLUIDITY.

V	15°–25°	25°–35°
10	0.0322	0.0290
Solv.	0.0335	0.0283

DISCUSSION OF RESULTS.

Tables III to XXII, inclusive, give the molecular conductivity, dissociation, viscosity and fluidity, as well as the temperature coefficients both of conductivity and fluidity for all the salts studied.

In this laboratory, during the past fifteen years, solutions in the following pure solvents have been investigated: Water, methyl and ethyl alcohols, acetone, and glycerol. Among the results of this work in pure solvents are the discovery or confirmation of many relations between the conductivity and viscosity of solutions, the dissociation of the solutes, and the dielectric constant, association factors and viscosities of the solvents.[13] Reference to Table II shows that formamid is a solvent markedly different from any other pure solvent investigated, in regard to the three constants mentioned. The most important result of this investigation is that the evidence it has developed supports and confirms all the relations and conclusions that have been worked out by Jones and his co-workers, from their investigations with other pure solvents. These relations will be discussed in turn.

The Thomson [14]-Nernst [15] theory is that the forces which hold the atoms together are electrical; hence the solvent having the highest dielectric constant has the greatest dissociating power. The dissociating power of solvents is shown in two ways: first, by comparing the percentage dissociation of solutions having the same normality; and, second, by comparing the dilutions at which complete dissociation is reached. Compare Table VII with the following:

---

[13] These results have been tabulated and discussed in Publications of the Carnegie Institute Nos. 170, 180, and 210.

[14] *Phil. Mag.*, 36, 320 (1893).

[15] *Zeit. phys. Chem.*, 13, 531 (1894).

Aqueous potassium iodide solution at 25

V			Temperature percentage coefficient, 25°–35°
2	112.8	76.6	1.85
8	120.7	82.0	1.97
2048	147.2	100.0	2.04

Table VII shows that the dissociation of the N/2 solution of potassium iodide in formamid is only 71 per cent. at 25°. From the data we calculate that the viscosity of the N/2 solution is 12.4 per cent. greater than the solvent, while the viscosity of N/2 solution of potassium iodide in water is known to be less than that of the solvent. From a large mass of evidence we know that viscosity is by far the largest factor affecting conductivity in solutions in which dissociation is of the same order of magnitude. The conductivity of the N/2 solution in formamid at 25° is 18.67. We can assume without appreciable error that if the viscosity of the solvent and the N/2 solution were in the same ratio as in the case of the potassium iodide solution in water, the conductivity of the N/2 solution in formamid would be at least 12.4 per cent. larger than the figure given—18.67. Recalculating the dissociation of the potassium iodide-formamid solution on this basis gives 79.4 per cent., compared with 76.6 per cent. for the potassium iodide solution in water. This latter figure would be even less if corrections were made for the fact that the viscosity of an N/2 solution in water is less than that of the solvent, which would be a legitimate correction to make for the purpose of this comparison. Comparing in this way the dissociation of these two N/2 solutions, we find, as would be expected from the Thomson-Nernst theory, *that formamid has the greater dissociating power.*

Complete dissociation of potassium iodide in formamid is found in the N/200 solution, while in water it is not reached till the N/2048 solution. Therefore, in both respects, formamid falls in line with the Thomson-Nernst theory. This relation is confirmed by every salt studied in this investigation for which data for comparison are available. The rubidium salts show the stronger dissociating power of formamid much more than some others that were studied.

The hypothesis of Dutoit and Aston[16] states that the greater the association factor of the solvent, the greater its dissociating powers. Table I shows the relation of formamid to other pure solvents in regard to association factors. The correction and comparisons made above, with reference to the Thomson-Nernst theory, are equally applicable in connection with the Dutoit and Aston theory. Having these two theories in mind, it is of interest to give here the percentage dissociations of a few salts in ethyl alcohol, for comparison with the data given in Tables VII, VIII, and XIX.

Solutions in Ethyl Alcohol at 25°.

Salt	V for	α
KI	8192	76.7
KCNS	6400	93.8
$LiNO_3$	6400	89.9

The above table was taken from the data of Jones and Kreider. Jones and Mahin showed that complete dissociation of lithium nitrate in acetone is not reached even when V is 100,000. The significance of these figures is apparent if one has in mind the association factors and dielectric constants of formamid, ethyl alcohol, and acetone, given in Table II.

Jones and Veazey's[17] explanation of the decrease in viscosity produced to the greatest extent by cæsium and rubidium salts, and in a less degree by potassium, ammonium, and other salts, all having very large molecular and atomic volumes, has been of special interest in this investigation. They base their hypothesis on the theory of Thorpe and Roger, that viscosity is due to the friction between the surfaces of the molecules. If the particles of the solute are larger than those of the solvent, the frictional surfaces and, consequently, the viscosity will be decreased. If the added particles are smaller than those of the solvent, the viscosity will be increased by the addition of the solute. The viscosity of all the concentrated solutions of salts having very large atomic or molecular volumes has been found to be less than the solvent in the case of all pure solvents, except acetone, which have previously been studied. The viscosity of formamid has, on the contrary, been *increased* by every salt used. The complex formamid molecule, $HCONH_2$, and its very large association factor, 6.18, show that its actual molecule is *larger than that of any other pure solvent used in these investigations,* and the increase in viscosity by the salts named above confirms this conclusion. The following comparison strikingly illustrates this relation: A N/2 solution of rubidium iodide in glycerol *decreases* the viscosity of the solvent 13 per cent., while a N/2 solution of the same salt in formamid *increases* the viscosity of the solvent 12.7 per cent. This relation will be referred to again in discussing the results of the work with cæsium nitrate and chloride.

---

[16] *Compt. Rend.*, 126, 240 (1897).

[17] *Amer. Chem. Journ.*, 37, 405 (1907).
Carnegie Institute of Washington, Publication No. 80, (1907).

That the percentage temperature coefficients of conductivity increase as the viscosity of the solution increases, is a relation that has been brought out by all the investigations in this laboratory. These coefficients for solution in formamid have the order of magnitude that would be expected from the relation of their viscosities to the viscosities of the same solutions in other solvents. For example, compare the coefficients for solutions of potassium iodide in water, given in the table on page 595, with those for the same salt in formamid in Table VII.

All salts containing water of crystallization were carefully dehydrated at suitable temperatures, just before the solutions were prepared. No thermal measurements were made of the heat of solution, but in the case of sodium iodide, which crystallizes with two molecules of water, a marked rise in temperature was noted when the salt dissolved in formamid, which indicated the formation of a solvate. It is well known that solvated salts give higher temperature percentage coefficients of conductivity than non-solvated, because complexes are usually simplified by rise in temperature. In the present investigation, salts crystallizing with water have given the larger coefficients, indicating the formation of solvates analogous to the formation of solvates by the same salts in water and other solvents. To illustrate this relation, let us compare these coefficients for sodium chromate, crystallizing with ten molecules of water (Table V), and cobalt bromide, crystallizing with two molecules of water (Table XXII); also compare sodium iodide, crystallizing with two molecules of water (Table IV), with potassium iodide (Table VII). The coefficients for the dilute solutions of sodium chromate are probably not reliable for this comparison, as will be explained under the discussion of this salt.

SODIUM CHROMATE.

Table V gives the results for sodium chromate. They are of the usual order of magnitude, except for the N/1600 solution. At each temperature the increase in conductivity between the N/800 and N/1600 solutions is 59 per cent., which is probably due to chemical action or decomposition, instead of to an increase in ionization. Formic acid is a strong reducing agent. Formamid may be considered as formic acid in which a hydroxyl has been replaced by an amido group. Both the hydroxyl and amido group are basic; therefore, we might expect from this relationship that formamid would be a reducing agent. The reducing action of formamid will also be discussed with the results for mercuric chloride. Sodium chromate is a strong oxidizing agent; hence, it is not surprising that there should be chemical action between these two compounds when the chromate is in a highly ionized condition, as in a dilute solution. The percentage dissociations have not been calculated, because the conditions just referred to introduce an uncertainty regarding them.

MERCURIC CHLORIDE.

The conductivity of aqueous solutions of mercuric chloride is too small to be measured, but in formamid, on account of its greater dissociating power, the conductivity is measurable, and increases as dilution increases in the usual way up to the N/400 solution. The conductivity values for the N/1000, N/1600, and N/3200 solutions clearly result from some decomposition, probably of the solvent. The conductivity of barium chloride at complete dissociation is 55.86 at 25°. The large value, 134.49, for the N/1000 mercuric chloride solution shows that it is not due to dissociation. Assuming that at complete dissociation the conductivity of mercuric chloride would be of the same order of magnitude as of barium chloride, the dissociation of the N/4 solution would be about 1.0 per cent., increasing to about 7.0 per cent. for the N/400 solution. Silver chloride is precipitated in the N/400 solution by silver nitrate. By standing in the sunlight for a short time, a heavy precipitate of metallic silver is formed, showing again the reducing action of formamid.

To recover the solvent from the mercuric chloride by vacuum distillation required several more distillations than usual. Metallic mercury was found in the receiver after the first distillation, showing again the reducing action of formamid. It is possible that the liberated chlorine formed a salt with the formamid which was easily dissociated, since the conductivity of the first fraction of the distillate was very high, and was lowered only a small amount by successive distillations. Repeated distillation, however, gave the solvent used for the solutions of the cæsium salts.

COBALT BROMIDE.

The green, anhydrous cobalt bromide gives a pink solution in formamid as in water. After the determinations were made, a mixture of solutions was distilled to recover the formamid. The mixture contained mercuric chloride and cobalt bromide. As already stated, the mercuric chloride was reduced to metallic mercury. The dry residue in the distillation flask had the brilliant blue color of anhydrous cobalt chloride, showing that the free chlorine from the mercuric chloride had replaced the bromine in the cobalt bromide.

CÆSIUM NITRATE AND CHLORIDE.

For several years past this laboratory has been unable to obtain any cæsium salts for its investigations in conductivity and viscosity. Recently, some cæsium sulphate was obtained through the coöperation and courtesy of Prof. James Lewis Howe, of Washington and Lee University. The sulphate was converted into the nitrate and chloride, and the conductivity and viscosity of their solutions were determined. The results are recorded in Tables XVII and XVIII.

A survey of the work on the salts of all the alkali metals shows that conductivity values for the cæsium, rubidium, and potassium salts used are approximately the same, and for sodium and lithium are less. The same relation is true of the results obtained in aqueous solutions. Dissociation percentage is of the same order of magnitude for all the salts named. The conductivity results in connection with the dissociation percentage harmonize with the ionic velocities. For cæsium, rubidium, and potassium the relative ionic velocities are 73.6, 73.5, and 70.6, respectively, and for sodium and lithium they are 49.2 and 39.8.

The most striking difference between these metals is shown by the atomic volume curve of Lothar Meyer.[18] This function increases by nearly regular steps from 12 for lithium to 72 for cæsium. In accordance with the theory of Jones and Veazey,[19] to which reference has already been made, the percentage increases in the viscosity of the concentrated solutions over the viscosity of the solvent should be the smallest for cæsium salts, and should increase in the following order: Cæsium, rubidium, potassium, sodium, and lithium. This relation comes out clearly by comparing the viscosity data for cæsium and rubidium salts (Tables XIII to XVIII) with those for sodium and lithium. The salts of rubidium and cæsium increase the viscosity of formamid much less than sodium and lithium salts (Tables III, IV, and XIX). The difference in percentage increase is not as marked as the difference in the atomic volumes of the metal ions. The effect is partially suppressed by other factors. Consider the solution of a binary salt which is 80 per cent. dissociated. Every hundred molecules of the salt gives, in solution, eighty anions, eighty cations and twenty molecules. The eighty cations are only 44.5 per cent. of the number of particles in the solution. It is only this 44.5 per cent. of cations which have the atomic volume relations referred to above. The molecular volumes do not show this relation, and the atomic volumes of the anions are unknown.

SUMMARY OF RESULTS.

The first five of the conclusions drawn below have been developed or confirmed by the investigations in this laboratory with other pure solvents, and have been shown by this investigation to hold true for formamid.

1. The greater the dielectric constant of a solvent the greater its dissociating power.

2. The greater the association factor of a solvent the greater its dissociating power.

---

[18] *Lieb. Ann. Suppl.*, 7, 354 (1870).

[19] Carnegie Institute of Washington, Publication No. 80, (1907); *Amer. Chem. Journ.*, 37, 405 (1907).

3. The formation of *solvates* with formamid is indicated by those salts that form hydrates.

4. Solvated salts show larger percentage temperature coefficients of conductivity than non-solvated salts.

5. The order of magnitude of percentage temperature coefficients of conductivity is approximately proportional to the viscosity of the solutions.

6. Formamid is the first of the pure solvents studied with reference to the viscosity of solutions, in which none of the salts used produce negative viscosities. A satisfactory explanation of the above fact is apparent, if the very large association factor of the solvent is considered in connection with the theory of Jones and Veazey.

7. In regard to conductivity, dissociation, and effect on viscosity of solvent, cæsium salts are very closely allied to rubidium salts.

8. Mercuric chloride is more dissociated in formamid than in water.

Johns Hopkins University,
May 15, 1915.

Metropolitan Needs and Sizes of Prime Movers. ANON. (*Electrical World,* vol. 66, No. 15, October 9, 1915.)—With the advent of the 20,000-kilowatt steam turbine many of the problems then confronting large modern generating stations were solved. However, the equipment soon proved to be too small to meet the rapidly advancing loads. The installation of 30,000-kilowatt and 35,000-kilowatt since has made another step forward in meeting pressing metropolitan needs, and now units of 50,000-kilowatt rating are being seriously considered. High economy and reliability are not the only desiderata in increasing the size of prime movers. Labor, real estate, and other considerations depending upon loads, design, and location of plant in a large city are factors almost as important. Recently many of the large lighting companies have acquired huge railway loads, it being generally recognized by railway officials that this is advantageous to them.

In New York City 30,000-kilowatt units are used to handle the elevated-railway and subway demand of the Interborough Rapid Transit Company. Units of 20,000 kilowatts are used by the central stations of New York, Cleveland, Detroit, and Chicago, and 30,000-kilowatt units in New York, Chicago, and Philadelphia. Philadelphia has the distinction of possessing the largest steam turbine thus far installed, a 35,000-kilowatt unit.

Stellite. E. HAYNES. (*Proceedings American Institute of Metals,* September 28 to October 1, 1915.)—The name "Stellite" is applied to an alloy of cobalt and chromium. By the addition of tungsten or molybdenum, or both, very hard alloys are formed, capable of scratching any steel that can be produced suitable for cutting tools for machining iron and steel. The value of the stellite tool lies in its ability to maintain its cutting edge at high speed at temperatures which would cause the failure of any known tools containing a notable quantity of iron. A stellite tool 3/8 inch square by 2½ inches long is reported to have turned off more than 8000 pounds of cast iron before becoming too short for use. Considering only the portion of the tool ground away, it turned off 1000 times its own weight.

A New Method of Making Sulphuric Acid. ANON. (*Commerce Reports,* No. 222, September 12, 1915.)—A new method of manufacturing sulphuric acid, for which advantages are claimed, is suggested in the United States Department of Agriculture Bulletin No. 283, "The Production of Sulphuric Acid and a Proposed New Method of Manufacture." The essential difference of the method from the usual one is that the gases employed are drawn downward through a spiral flue in place of being drawn through lead chambers or intermediate towers. It is asserted that the resistance of gases to the downward pull and the constant change in their course through the spiral tend to mix them very intimately. The fact that the gases constantly impinge on the walls of the spiral flue, which can be cooled by either air or water, makes it practicable to maintain the gases at a temperature most favorable for the efficient yield of sulphuric acid.

The method has been tried only on a laboratory scale, and the bulletin refuses to predict just how efficient the commercial plant would be, but states that all indications are that this method offers promise of being economically successful.

Bibliography of Chemistry of Gas Manufacture. (*United States Bureau of Mines, Technical Paper No. 120.*)—A bibliography of the chemistry of gas manufacture has just been issued by the United States Bureau of Mines. The references in this bibliography have been selected from a much longer list gathered by the Bureau during several years of research work on problems dealing with the chemical behavior of hydrocarbons. No attempt is made to cover every phase of gas manufacture, including the construction and operation of plants, the object being to present a bibliography of carefully-chosen references dealing with the chemistry of gas making and the chemical changes involved in the production of combustible gases.

In view of the fact that there is no such published bibliography, the list, together with its cross-references, is published by the Bureau of Mines in the hope that it will serve as an efficient guide for investigators, chemists and engineers, and for operators of gas plants.

ON THE RETENTION OF ACTIVITY BY UREASE AND BY OXIDASE AFTER EXPOSURE TO THE TEMPERATURE OF LIQUID AIR.

BY

JOSEPH SAMUEL HEPBURN, A.M., B.S. in Chem., M.S., Ph.D.,
Member of the Institute,

AND

CHARLES BLIZARD BAZZONI, A.M., B.S., Pd.B., Ph.D.,
Instructor in Physics, Randal Morgan Laboratory, University of Pennsylvania.

ALTHOUGH several investigators have subjected solutions of enzymes to the temperature of liquid air, the time of exposure has rarely exceeded one hour. Pozerski [1] kept pepsin, trypsin, invertase, diastase, and inulinase at that temperature for 45 minutes, rennin for one hour. Chanoz and Doyon [2] held thrombin at that temperature for 13 minutes, rennin for periods of 1, 5, 10, and 30 minutes. Macfadyen [3] subjected zymase to the temperature of liquid air for 20 hours. Each of these enzymes was usually found to retain its full activity after having been exposed to this exceedingly low temperature. The methods used to determine the enzymic activity were, however, qualitative as a rule.

In the present study, the activity of an aqueous solution of urease was quantitatively measured before and after subjecting it to the temperature of liquid air for a period of 100 hours.

The temperature of liquid air lies between the boiling-point of nitrogen and that of oxygen. Fischer and Alt [8] give the boiling-point of liquid nitrogen at a pressure of 760 mm. as 77.33° ± 0.05° absolute or –195.67° C. Travers, Senter, and Jaquerod [9] give the boiling-point of liquid oxygen at a pressure of 760 mm. as 90.10° absolute (–182.90° C.) when determined on the hydrogen scale, 90.20° absolute (–182.80° C.) when determined on the helium scale.

The urease was the commercial article, prepared from the soy bean *Glycine hispida,* and contained five per cent. of potassium phosphate.[4] A solution of 1 gramme of the enzyme to each 10 c.c. of water was used.

The solution of the enzyme was frozen by placing it in a thin-walled glass test-tube, which was then plunged in liquid air contained in a transparent Dewar flask. In order to avoid rupture of the test-tube by the expansion of the solution in freezing, it was necessary to freeze slowly and to add the enzyme solution in successive increments of 1 c.c. The total volume frozen in the tube was 11 c.c.

The tube and its contents were then transferred to a silvered Dewar bulb, containing liquid air. This bulb was heavily insulated with felt. The level of the liquid air was initially above that of the frozen enzyme solution, and this relation was maintained throughout the 100 hours by addition of liquid air at intervals.

At the end of 100 hours the test-tube and its contents were removed from the Dewar bulb, and the enzyme solution was permitted to thaw at the temperature of the room. The activity was then determined.

In order to measure the activity of the urease, 5 c.c. of the thawed solution were mixed with 25 c.c. of the substrate solution and were then incubated for 15 minutes at 40° C. The substrate[4] contained in 100 c.c.:

4.3 grammes dipotassium phosphate.
3.4 grammes monopotassium phosphate.
6.0 grammes urea.

Several grammes of potassium carbonate and sufficient alcohol to prevent foaming during the aëration were then added, and the ammonia, liberated by the enzyme, was determined by aspiration for one hour, collecting the ammonia in an excess of $\frac{N}{10}$ sulphuric acid, and titrating the excess of acid with $\frac{N}{10}$ sodium hydroxide, using Congo red as the indicator. Five cubic centimetres of the thawed enzyme solution were inactivated by boiling, and were used in a blank experiment. A determination proper and a blank experiment had been carried out on a portion of the original urease solution immediately after its preparation. The quantity of enzyme and of substrate, the period and temperature of incubation, and the mode of estimation of the ammonia formed were exactly as outlined above.

For comparison, a quantitative determination was also made of the activity of another portion of the enzyme solution, after holding in a thermostat at 20° C.—approximately room temperature—for 100 hours. In order to exclude bacterial action, sufficient trikresol had been added to make this a 0.2 per cent. solution of that bactericide. Graves and Kober[5] have used this strength of trikresol in their recent study of urease. The mode of estimation of the enzymic activity was the same as already described.

The number of cubic centimetres of $\frac{N}{10}$ ammonia found in the corresponding blank has been subtracted from the number found in each determination proper; the remainder, which represents the ammonia liberated by the enzyme from the urea, is given in the table:

	Ammonia liberated by urease, c.c. $\frac{N}{10}$ NH_3	Per cent. of enzymic activity retained
Fresh	49.90	
After 100 hours in liquid air	48.05	96.29
* After 100 hours at 20° C.	22.15	44.39

---

*Used 0.2 per cent. trikresol as a bactericide.

The tabulated results show that, during prolonged exposure to the temperature of liquid air, urease suffers but a slight loss of its power to hydrolyze urea. The loss of enzymic power was far more pronounced at approximate room temperature, even though the urease was protected by a bactericide.

Oxidase.—So far as the authors know, the resistance of oxidase to the temperature of liquid air has not hitherto been studied.[6] One cubic centimetre of a ¼ per cent. aqueous solution of potato skin oxidase—cresol tryosinase of Chodat[7]—was frozen in the manner described above, and then held in liquid air for 3½ hours. The solution, after having thawed, retained its power to produce a cherry-red color with a 1 per cent. aqueous solution of Witte peptone plus a dilute aqueous paracresol solution.

REFERENCES.

[1] Pozerski, *Comptes rendus de la Société de Biologie,* 1900, lii, 714.

[2] Chanoz and Doyon, *Comptes rendus de la Société de Biologie,* 1900, lii, 453.

[3] Macfadyen, *Proceedings of the Royal Society of London,* 1900, lxvi, 180; *Lancet,* 1900, lxxviii (1), 849.

[4] Van Slyke and Cullen, *Journal of Biological Chemistry,* 1914, xix, 211.

[5] Graves and Kober, *Journal of the American Chemical Society,* 1914, xxxvi, 751.

[6] Hepburn, *Biochemical Bulletin,* 1915, iv, 136; JOURNAL OF THE FRANKLIN INSTITUTE, 1915, clxxix, 581; *Ice and Refrigeration,* 1915, xlviii, 348.

[7] Chodat, *Archives des Sciences Physiques et Naturelles,* Serié iv, 1912, xxxiii, 70.

[8] Fischer and Alt, *Annalen der Physik,* 4 Riehe, 1902, ix, 1149.

[9] Travers, Senter and Jaquerod, *Chemical News,* 1902, lxxxvi, 62.

Special Rowboats for Outboard Motors. ANON. (*Motor Boating,* vol. xvii, No. 3, September, 1915.)—Several years ago a compact gasoline engine power plant was introduced, arranged to be easily attached at the stern of a rowboat and as easily removed. It was designed primarily for existing rowboats, but as its use became widespread it grew apparent that the ordinary rowboat could be improved upon in certain ways, resulting in the production of boats especially designed for use with the outboard motor.

The differences in design of the new rowboat consist chiefly in the use of stronger stern transoms to bear the weight of the attached motor, changes in the hull displacement so that with the motor in place and the operator sitting near it the bow will not be thrown out of the water, and general sturdier construction to meet increased speed and augmented passenger capacity.

It is not to be thought that the old-fashioned rowboat will not prove satisfactory, but there has been a demand by owners of outboard motors for something just a little more suited to their power plants, and so, in the last year or two, nearly a score of boat builders are offering " outboard motor rowboats," as they are called.

Boiler Repair Ships. ANON. (*The* (London) *Times Engineering Supplement,* No. 490, August 27, 1915.)—The employment of welding for repairs to boilers in ships has now become quite common, and special boats are frequently constructed in which all the apparatus for the purpose is fitted.

In some interesting craft of this kind which have recently been put into service in Sweden, Diesel engine sets are installed. A 3-cylinder, 37-h. p. motor running at about 550 r. p. m. is coupled to an air compressor, compressing up to about 100 pounds per square inch, and also a dynamo which provides the current not only for welding but also for propelling the boat by means of an electric motor placed in the stern. The compressed air is used for the pneumatic tools required in carrying out the repairs.

Properties and Uses of Military Explosives. L. CRESAP. (*The Iron Age,* vol. 96, No. 14, September 30, 1915.)—From a military point of view there are two distinct classes of explosives—slow and fast. The slow explosives, whose rate of decomposition or burning can be controlled, are used as propellants for projectiles in guns. The fast explosives are those in which the rate of burning is not controlled and explode or burn with the greatest possible rapidity. Such explosions are generally called detonations and find application in shells, mines, torpedoes, etc.

The interval of time occupied by these classes of explosives is a distinguishing feature. The explosion of a slow explosive occurs in a period greater than one-fiftieth of a second, while in a high explosive measurements have shown some detonations to spread at a rate of 10,000 feet per second.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

A NEW RELATION FROM PLANCK'S LAW.

By Paul D. Foote.

[ABSTRACT]

NUMEROUS displacement laws may be derived from the Planck relation representing the spectral distribution of the energy radiated by a black body. In the present paper a new displacement law is derived which states that the product of the absolute temperature θ and the λ – component of the centre of gravity of the spectral energy curve λ_c is a constant, as follows:

$$\theta\lambda_c = 0.37021\ C_2$$

where C_2 is the characteristic constant of the Planck equation.

THE MICROSTRUCTURAL CHANGES ACCOMPANYING THE ANNEALING OF BRONZE (Cu88, Sn10, Zn2).

By Henry S. Rawdon,

Assistant Physicist.

THERE is a common misunderstanding among metal workers in regard to the "grain refining" or recrystallization of brass and bronze upon annealing, many regarding the change in the same light as the "grain refining" of steel. This study shows the modifications which occur in the microstructure and the temperatures at which such changes are completed. Zinc bronze, of the composition indicated above, was used as a type, because of its commercial importance and also to supplement the other work on this alloy which has been carried out by the Bureau of Standards.

After casting, the alloy exhibits a complex structure consisting of a dendritic matrix consisting of a solid solution of tin (and zinc) in copper in which are embedded numerous particles of a hard and brittle eutectoid. Upon annealing, the alloy is first rendered homogeneous by the absorption of the eutectoid by the matrix and the disappearance of the dendrites in this same matrix. If the alloy has suffered no deformation previous to annealing, no other changes are observed; the crystal or grain size remains unchanged. The characteristic polyhedral twinned crystals seen in annealed brass and bronze, rich in copper, are obtained only after the structure is distorted previous to heating. Samples which have been cooled in a very drastic manner, thus inducing severe internal strains, behave similarly upon annealing to those which have been mechanically deformed.

---

* Communicated by the Director.

The samples used were cylinders, the surface layer of which has been distorted by machining in the lathe. These were then annealed for periods of one, two, four, and eight hours at 400°, 600°, and 800° C. The constancy of the thickness of the recrystallized layer (different for different temperatures), after different annealing periods at the same temperature, is very striking. Though the crystals in this layer of recrystallized metal increase in size, there is no appreciable increase in thickness, thus substantiating Tammann's theory of recrystallization of "cold-worked" metals upon heating.

COMPRESSIVE STRENGTH OF PORTLAND CEMENT MORTARS AND CONCRETES.*

By R. J. Wig, G. M. Williams, and E. R. Gates.

[ABSTRACT]

CONCRETE differs from most structural materials in that it is not manufactured at a mill or plant according to chemical formula, under the observation of skilled specialists, subject to rigid inspection and test and such control as to produce a uniformly homogeneous product; nor is the process of manufacture completed in a few hours or days, as in the case of steel products. Furthermore, concrete is made from materials obtained from many sources, differing widely in characteristics which affect its quality. The proportions of the ingredients, the amount of water used in mixing, the thoroughness of mixing, the manner of placing, the atmospheric temperature and humidity, exposure to sun, rain, and wind, immersion in fresh water or sea-water, or other natural solutions, all affect the quality of concrete.

This paper is a collation and study of about 20,000 tests of mortars and concretes which have been made in connection with the routine and investigative work of the Bureau of Standards and the Structural Material Laboratories of the United States Geo-

---

* Technologic Paper No. 58.

logical Survey which were transferred to the Bureau of Standards in 1910. Tests were made of about 150 different aggregates, consisting of limestones, granites, gravels, trap rocks, and cinders. Studies have been made to determine the effect of the several variables enumerated above, and a summary of the results and the conclusions are given below.

SUMMARY.

Portland Cement Mortar Mixtures.—Sands as a type of fine aggregates cannot be said to be superior to limestone screenings.

The proper gradation of the fine aggregate for maximum strength in mortar appears to vary with the material.

The results of the tests of the mortars included in this paper would indicate that for most materials the highest strengths are obtainable with those having a gradation of particles approaching a straight line. There are materials, however, which have a gradation varying widely from a straight line which give high strength in mortars.

The quality of a sand cannot be judged from its gradation alone. Any limitation arbitrarily placed upon the proportions of the particles of various sizes will probably eliminate some very satisfactory materials.

No fine aggregate should be rejected because of its "silt" content determined by washing or assuming the material passing the No. 200 sieve as silt, as it may be advantageous even in relatively large quantities or detrimental in small quantities, depending upon its form and distribution. Mortars made from sands having rounded grains have equal strength with mortars made from sands having sharp grains.

The only satisfactory method of determining the value of a fine aggregate in mortar mixtures is to test it in the mixture in the same proportion to be used, exposed to the same conditions as in the proposed structure.

Common usage has demonstrated that certain sands are satisfactory, and therefore no tests of these materials are necessary excepting to identify them.

The relative value of several fine aggregates to be used in concrete cannot be determined by testing them in mortar mixtures. They must be tested in the combined state with the concrete aggregate.

Portland Cement Concrete Mixtures.—No type of gravel or stone aggregate can be said to be generally superior to any other type used as coarse aggregate in concrete mixtures. Certain limestones are superior to certain gravels, and some gravels are better than other limestones. The range of qualities in any of these types is very great, and the strengths of concretes made up of several materials of the same type may vary as much as several hundred per cent., with all other controllable factors uniform.

Relation of Workmanship to Compressive Strength.—Undoubtedly greater uniformity is generally obtained by machine mixing than by hand mixing. The method of mixing is of little importance so long as it results in a homogeneous mass. Using proper methods and with the expenditure of sufficient labor, results indicate that as good concrete can be obtained by hand mixing as by machine mixing, although it probably would not be economical.

With all other factors constant, the results included in this paper show that differences in manipulation of the mixture by the workmen of several experienced concrete contractors may cause a maximum average variation in the compressive strength of the resulting concrete of 70 per cent. or more.

Relation of Consistency of Mixture to Compressive Strength.—The quantity of water added to the mixture in preparing concrete affects materially the compressive strength at all ages With the proper quantity of water the strength may be several hundred per cent. greater than that obtained with a large excess of water.

The most satisfactory consistency from the standpoint of strength and durability is a quaking mixture, and the error should be on the side of using too little rather than too much water, providing it is properly spaded or worked into place in the forms. This statement does not apply to the very dry mixtures used in the manufacture of concrete blocks, etc. In the case of these products the mixture should contain the maximum quantity of water which will permit of the immediate removal of the moulds. This mixture has less water than the quaking consistency described above.

Relation of Density to Compressive Strength.—With the same aggregates and the same proportion of cement to total volume of aggregate the mixture having the greatest density will have a high, and usually the highest, compressive strength.

Density is no criterion of compressive strength of two mixtures of an aggregate if the ratio of cement to total volume of aggregate is not the same.

Density is no criterion of compressive strength of two mixtures of the same proportions of cement to total aggregate if different aggregates are used, although where the aggregates are quite similar they may be comparable.

Effect of Various Exposures on Compressive Strength.—The character of the exposure of the concrete after moulding materially affects its compressive strength. If the original water is permitted to evaporate from the concrete and all water is subsequently excluded, the compressive strength may be reduced 40 per cent. or more. Concrete should preferably be kept wet for several days or weeks after it is deposited if the maximum strength is to be attained.

Effect of Exposure to Steam on Compressive Strength.—Steam greatly accelerates the hardening process, and will increase the strength of concrete only a few days old by several hundred per cent., depending upon temperature and duration of exposure.

Relation of Gradation of Aggregate to Compressive Strength.—There is no definite relation between the gradation of the aggregate and the compressive strength which is applicable to any considerable number of different aggregates.

The gradation curve for maximum compressive strength, usually the same as for maximum density, differs for each aggregate.

The so-called " maximum density curve," which is a combination of the straight line and ellipse, does not represent the curve for maximum density excepting for the particular materials used in the tests from which it was derived, or very similar materials.

No equation for a gradation curve, which can be applied to a number of different aggregates, can be prepared from the results included in this paper.

Excessive fineness does not necessarily result in a totally unsatisfactory sand for concrete. A sea-shore sand having 99 per cent. passing a 50 mesh sieve when mixed with a good aggregate and cement was found to give a satisfactory concrete.

CONCLUSIONS.

1. No standard of compressive strength can be assumed or guaranteed for concrete of any particular proportions made with any aggregate unless all the factors entering into its fabrication are controlled.

2. A concrete having a desired compressive strength is not necessarily guaranteed by a specification requiring only the use of certain types of materials in stated proportions. Only a fractional part of the desired strength may be obtained unless other factors are controlled.

3. The compressive strength of a concrete is just as much dependent upon other factors, such as careful workmanship and the use of the proper quantity of water in mixing the concrete, as it is upon the use of the proper quantity of cement.

4. The compressive strength of concrete may be greatly reduced by the use of an excess of water in mixing to a fractional part of that which it should attain with the same materials. Too much emphasis cannot be placed upon the injurious effect of the use of excessive quantities of water in mixing the concrete.

5. The compressive strength of concrete may be greatly reduced if after fabrication it is exposed to the sun and wind or in any relatively dry atmosphere in which it loses its moisture rapidly even though suitable materials were used and proper method of fabrication employed.

6. The relative compressive strength of concretes to be obtained from any given materials can be determined only by an actual test of those materials combined in a concrete.

7. Contrary to general practice and opinion, the relative value of several fine aggregates to be used in concrete cannot be determined by testing them in mortar mixtures. They must be tested in the combined state with the coarse aggregate.

8. Contrary to general practice and opinion, the relative value of several coarse aggregates to be used in concrete cannot be determined by testing them with a given sand in one arbitrarily selected proportion. They should be tested in such combination with the fine aggregates as will give maximum density, assuming the same ratio of cement to total combined aggregate in all cases.

9. No type of aggregate such as granite, gravel, or limestone can be said to be generally superior to all other types. There are good and poor aggregates of each type.

10. By proper attention to methods of fabrication and curing, aggregates which appear inferior and may be available at the site of the work may give as high compressive strength in concrete as the best selected materials brought from a distance, when the latter are carelessly or improperly used.

11. Density is a good measure of the relative compressive strength of several different mixtures of the same aggregates with the same proportion of cement to total aggregate. The mixture having the highest density need not necessarily have the maximum strength, but it will have a relatively high strength.

12. Two concretes having the same density but composed of different aggregates may have widely different compressive strengths.

13. There is no definite relation between the gradation of the aggregates and the compressive strength of the concrete which is applicable to any considerable number of different aggregates.

14. The gradation curve for maximum compressive strength, which is usually the same as for the maximum density, differs for each aggregate.

15. With the relative volumes of fine and coarse aggregate fixed the compressive strength of a concrete increases directly, although not in the same proportion as the cement content. An increase in the ratio of cement to total fine and coarse aggregates when the relative proportions of the latter are not fixed does not necessarily result in an increase in strength, but may give even a lower strength.

16. The compressive strength of concrete composed of given materials, combined in definite proportions and fabricated and exposed under given conditions, can be determined only by testing the concrete actually prepared and treated in the prescribed manner.

STANDARD TEST SPECIMEN OF ZINC BRONZE (Cu_{88}, Sn_{10}, Zn_2). PART II—MICROSTRUCTURE.

By Henry S. Rawdon,
Assistant Physicist.

[ABSTRACT]

THE work constitutes a part of the study of the properties and structure of standard alloys undertaken by the Bureau of Standards at the request of the American Institute of Metals.

This study of the microstructure supplements the determination of the physical properties and endeavors to explain some of the differences observed.

Simple reference is made to the equilibrium diagrams of copper and tin and copper and zinc in order to explain the struc-

ture to be expected in such alloys. The examination of a large series of specimens cast by the different methods chosen (Part I) shows that the structure is affected only indirectly by the rate of cooling, inclusions of foreign materials, etc. The characteristic appearance of tensile bars of the alloy after breaking is explained and the relation to the microstructure of the cast alloy shown.

Of all the microstructural features affecting the properties of the alloy, the presence of films and pits of oxide far outranks the others in the bad effects produced. The use of zinc alone as a deoxidizer appears not to be sufficient and dependable. The oxides occur both in the form of pits and thin branching films, the second form being the one especially pronounced in its effects. The changes in the microstructure of the alloy upon heat treatment are explained and illustrated, and the possible use of heat treatment to improve the properties of badly-oxidized metal is suggested.

A series of photomicrographs is included to illustrate the structure of the alloy and relation of the microstructure to other physical properties. The article has been made as non-technical as possible in order to appeal to a wide range of readers, including manufacturers and foundry men, as well as buyers and users of the alloy.

EARTH RESISTANCE AND ITS RELATION TO THE ELECTROLYSIS OF UNDERGROUND STRUCTURES.

By Burton McCollum and K. H. Logan.

THIS paper presents some of the results of the laboratory and field work of the Bureau of Standards carried on in connection with the study of electrolysis and its mitigation. The resistance of the soil in which metallic structures are buried is shown to be of much importance with respect to electrolysis of these structures. Three methods of measuring the specific resistance of the soil, two of which do not require the removal of the soil from its original position, are described. Results of soil-resistance measurements by each method are compared, and it is shown that any of the described methods is satisfactory for practical purposes, although each has advantages over the others under certain conditions.

The results of a large number of measurements of resistance of soil samples from widely-separated points in the United States have been tabulated. These data show great variations in soil resistance and indicate the desirability of a study of local soil conditions in connection with any complete electrolysis survey. The majority of soils tested show resistivities of between one thousand and five thousand ohms per centimetre cube.

A number of factors have been found to influence the resistivity of the soil. Increasing the pressure on a sample of soil under test tends to increase the conductance of the sample slightly, especially if the original pressure is low. Increase in moisture increases the conductance of the soil if it is not saturated with water. The amount and kind of soluble material in the soil affects its resistance. The resistance of soil is found to increase as its temperature falls, especially when the freezing-point of water is reached. The flow of current through the soil has been found to produce an apparent temporary increase in soil resistance in the neighborhood of the electrodes.

The relation of soil resistance to electrolysis is considered from the standpoint of leakage from street railway lines using the track as a return current. The importance of good rail bonding and of well-drained roadbed is pointed out.

The relations of the various factors affecting leakage resistance (namely, character of the soil, pressure, moisture, freezing and polarization, and surface films) to the electrolysis problem are described, and it is shown that a knowledge of the resistivity of the soil is of importance in estimating the danger indicated by potential difference and potential gradient measurements. It is also shown that the moisture and temperature of the soil materially affect the amount of current escaping from a grounded track used as a return circuit and that these factors must be given due consideration in the interpretation of data obtained during an electrolysis survey.

FOREIGN SPECIFICATIONS FOR RAILWAY MATERIAL.*

THE Bureau of Standards, in connection with its investigation of failures of railway material, has obtained, through the courtesy of the State Department and its consular service, the specifications for railway material—rails, wheels, axles, and tires—of the State railways of Germany, Austria, Italy, Belgium, and Sweden, as well as some of those of the railways of Great Britain, France, and Holland. The data available concerning accident statistics and derailments, as well as those bearing on the types and weights of railway equipment—rolling-stock and rails—have been also obtained in the same manner.

---

* To be published as a Circular of the Bureau of Standards, 1915.

These specifications, in so far as they concern rails, axles, wheels, and tires, are given practically in full as an appendix to a forthcoming Bureau Circular. The body of the circular contains a digest and discussion of the accident and derailment statistics, the data on railway equipment, and of the specifications themselves.

There appear to be no foreign statistics available concerning the removal for defects of such railway material as rails, wheels, and axles such as in the United States, but the derailment statistics of the foreign countries show in general a much smaller proportion of derailments due to such defects than is found in the United States.

A few of the many points brought out by a survey of these railway specifications may be mentioned here.

Foreign rails, wheels, and axles are relatively heavier for the traffic which they bear than those in the United States, and that the specifications and tests prescribed for the same are generally very stringent. In particular, drop and impact tests are almost always applied to all such types of railway material, and often this test is at the same time a fatigue or endurance test, which is known to be a very severe test of the quality and toughness of a material.

The chilled cast-iron car wheel is not used a great deal abroad, and hence is hardly mentioned in the specifications. Its place is taken by built-up wheels, consisting of wheel centre and tire, or by spoked wheels. These are made of wrought iron or of steel, forged or cast.

The practice is generally adhered to abroad of requiring a manufacturer's guarantee for such material. Rails, for example, are sometimes guaranteed for from five to six years.

NOTES FROM NELA RESEARCH LABORATORY.*

THE RELATION BETWEEN SPECTRAL COLOR AND STIMULATION IN THE LOWER ORGANISMS.

By S. O. Mast.

It is well known that many of the simplest organisms respond very definitely to light. Some orient and travel fairly directly toward the light, others away from the light, while still others go toward it under some conditions and away from it under others.

In a field of light consisting of two horizontal beams crossing at right angles these organisms proceed toward or from a point situated between the two beams. The location of this point depends upon the relative effective luminous flux illumination received by the organisms from these beams. If it is the same in quality and intensity, so that the stimulation is the same, the point lies approximately half way between them.[1] Consequently whenever the organisms proceed toward or from a point thus located it may be concluded that the stimulating effect of the light in the beams is equal, no matter how it may differ, either in intensity or in quality.[2] It is therefore obvious that if the light in one beam is kept constant in quality (white, for example), while that in the other is changed in color, the relative stimulating efficiency of the different colors can be ascertained. To do this, all that is necessary is to vary the luminous intensity of the white light for each change in the colored light, until, in each case, the organisms proceed on the same path. The stimulating effect of the different colors will then be directly proportional to the various luminous intensities of the white light required to make the organisms under each of the different conditions proceed in the same direction; *e.g.,* if for green, it requires twice the intensity of light from the white source to make the creatures take a given course as it does for yellow; then the stimulating effect of the green is twice as great as that of the yellow. To ascertain the relative efficiency in terms of wave-lengths and energy it is only necessary to use a spectrum having a known distribution of energy, and to make corrections in accord with this distribution.

---

* Communicated by the Director.

[1] Details as to the process of orientation in these organisms may be found in my book on "Light and the Behavior of Organisms," John Wiley & Sons, New York, 1911.

[2] This is literally true for only a few organisms, but the principle as applied holds for all, as will be demonstrated in a more comprehensive paper to be published elsewhere.

In the experiments referred to below, two gas-filled, street-series, tungsten lamps with coiled filaments were used in series to produce two beams of light. One of these beams passed through a Hilger constant deviation spectrometer, and the other through a Brodhun rotating sector. The whole apparatus was so arranged that the two beams of light crossed at right angles in the field of observation. For every color tested the intensity of the illumination in the beam of white light was adjusted by varying the opening in the sector until the course of the organisms bisected the angle between the two beams of light. In nearly all cases the successive regions selected in the spectrum differed by 10 $\mu\mu$.

In this way the relative stimulating effect for the different regions of the spectrum was ascertained in fifteen different species, as follows: *Chlamydomonas, Trachelomonas,* and *Phacus,* each one species; *Euglena,* five species; *Pandorina, Eudorina, Gonium,* and *Spondylomorum,* each one species; earthworms, *Arenicola* (larvæ), and blowfly (larvæ), each one species All but the last three are green, microscopic organisms, relatively very simple in structure.

The results obtained will be stated in terms of relative stimulative effects of the different regions of the spectrum tested, without corrections for the difference in the energy of these regions. They are, however, of such a nature that the corrections mentioned will not result in marked alterations. These corrections will appear in a subsequent paper.

For all but one of the microscopic organisms the results fall into two groups. In the one group the region of stimulation begins in the blue near the violet, between 430 and 440 $\mu\mu$. From here toward the red end of the spectrum the stimulating efficiency rises, at first slowly and then rapidly, to a maximum in the green near the yellow, between 530 and 540 $\mu\mu$; then it falls, at first rapidly and later more and more slowly, ending in the red at about 640 $\mu\mu$. In the other group the region of stimulation begins in the violet between 420 and 430 $\mu\mu$, only a short distance from the place where it begins in the first group. From here the efficiency rises very rapidly, reaching a maximum in the blue between 480 and 490 $\mu\mu$. It then falls rapidly, and ends in the green in the neighborhood of 520 $\mu\mu$. Three of the microscopic forms, *Pandorina, Eudorina,* and *Spondylomorum,* belong to the first group, the rest to the second. To this group belong also *Arenicola* larvæ and the earthworms. For the remaining microscopic form (*Chlamydomonas*) the maximum is in the green very near 510 $\mu\mu$; and for the blowfly larvæ it is approximately at 520 $\mu\mu$. The distribution in the spectrum, of stimulating efficiency is, for this creature, essentially the same as the distribution of brightness for totally color-blind persons.

These results show that stimulation in all of the organisms studied depends upon the wave-length of the light; that the stimulating efficiency is very much higher in certain regions of the spectrum than in others; but that the distribution of this in the spectrum differs greatly in certain organisms that are closely related in structure (*e.g., Pandorina* and *Gonium*), while it is essentially the same in others that are very different in structure (*e.g., Euglena* and earthworms). A more extensive study of this subject ought to lead to an insight into the chemical and physical phenomena that are associated with the reactions in these organisms.

TEMPERATURE AND BLACKENING EFFECTS IN HELICAL TUNGSTEN FILAMENTS.

By Benj. E. Shackelford,

(Charles F. Brush Research Fellow).

THE inside of glowing helical tungsten filaments is very much brighter than the outside. *A priori,* this may be due to internal reflections or to the inside being at a higher temperature than the outside. Coblentz[1] concluded that the major portion of the brightness difference was due to temperature difference between the two surfaces, aside from that due to inability to focus accurately on the edges of the filaments. According to Wodthing's[2] data on conductivity of tungsten at high temperatures, the maximum allowable difference in temperature between the outside and the inside of the filaments used is usually of the order of 1°, considering the limiting case of a cylinder. This means a difference in brightness of 0.5 per cent., whereas differences of the order of 100 per cent. are observed. The object of the present investigation, therefore, was to determine the causes of the difference in brightness of the two surfaces.

---

[1] *Electrical World,* vol. 64, p. 1048.

[2] *Physical Review,* December, 1914.

By means of a Holborn-Kurlbaum optical pyrometer brightness readings were taken on the outside and on the brightest portions of the inside of the filaments, excluding the edges because of the difficulty mentioned above and because of the deviation from the cosine law. Five gas-filled lamps were used containing helical filaments of the same size wire wound on the same mandril, but with different pitches, ranging from 1.35 to 3 times the diameter of the wire. In each case on going from the outside of the coil to the inside the red ($\lambda = 0.66\mu$ approximately) brightness increased relatively more than did the blue ($\lambda = 0.46\mu$ approximately); at a red black body temperature of 2250° K. this relative increase was 5 to 10 per cent. more, depending on the pitch. This shows that at least the greater part of the increase in brightness is due to internal reflections and not to the temperature being greater on the inside. If it were a temperature effect in the main, the radiation from the inside would be relatively stronger in the blue. In justification of the above method and conclusion it was found that by plotting the outside-inside brightness ratios against pitch a straight line was obtained. Extrapolating backward to pitch unity, which corresponds to a closed cylinder, it was found that the value of the ratio at 2250° K. was 0.442 for red glass, which agrees very closely with Worthing's value (unpublished) of the emissivity found by an entirely different method. The ratio for blue glass was 0.461. At 1875° K. the brightness ratios were greater, giving a higher value for the emissivity.

Using two templates cut to transmit only the inside and outside radiation respectively when the image of the filament was projected on them, one of the lamps was color-matched against a second helical filament. To match the outside, 0.05 per cent. greater current was necessary than to match the total radiation, and 2 per cent. less was required to match the inside, again showing that the inside is relatively redder than the outside, and that the larger part of the brightness difference is due to blackening.

A piece of 20-mil wire was flattened to 10 mils, after which it was polished and mounted as a helical filament and operated at 1800° K. Setting now on the darkest portions of the inside, there was only a 2 per cent. greater brightness on the inside than the outside, which means not more than 4° difference in temperature, assuming that to be the sole cause of the difference. Since the surface was not an optical one and some blackening still remained, the actual difference must have been less than this.

To summarize: The data show that the interior of the helical filament has a maximum brightness of the order of twice that of the exterior; that the inside is redder, and that the increased brightness in the main is due to internal reflections; that the temperature difference between the outside and inside of a 10-mil coiled filament is not greater than 4°; also a value of 0.442 is found for the red and 0.461 for the blue emissivity at 2250° K.

It is intended to continue the investigation by means of resistance measurements and by means of brightness measurements on a more perfectly polished flattened filament.

A Direct Reading Analytical Balance. ANON. (*Scientific American,* vol. cxiii, No. 15, October 9, 1915.)—In the present innovation in analytical balances, due to the efforts of Christian Baker, of New York, the weighing is accomplished by a small platinum or gold chain suspended at one end from an adjustable screw fitted to the beam of the balance, and at the other to a hook held by a sliding block. The block, which is marked with a vernier scale reading to one-tenth of a milligramme, is moved along its supporting scale by a vertical spiral drive in the rear, which in turn is rotated by a thumb-screw through bevel gears.

To operate the new balance it is only necessary to rotate the thumb-screw controlling the block so as to cause the leg of the chain hanging from the beam to be lengthened or shortened, adding more or less weight until balance obtains. The window of the balance is closed after the object to be weighed has been placed on the pan, and is left closed during the entire operation. The altering of the chain weight can take place while the beam is swinging, so that neither the pans nor the beam need be rested at any time during the weighing operation, resulting in a great saving of time. The range of the chain weight is considerable: in one of the most popular of these analytical balances it will weigh from one-tenth milligramme to 50 milligrammes. By using a lighter or heavier chain, the graduated scale can be calibrated for finer or coarser weighing.

Artificial Illuminants for Use in Practical Photography-cinematograph Work. C. E. K. MEES. (*Proceedings of the Illuminating Engineering Society,* September 20 to 23, 1915.)—In moving-picture studios a considerable amount of light is necessary, owing to the speed at which the pictures are taken, the exposure being only 1/40 of a second with an aperature of about F/8. The average stage, including an area of perhaps 240 square feet, requires about 60 kilowatts of illumination, and a typical arrangement of lights will consist of 40 to 50 kilowatts expended in mercury-vapor lamps or quartz arcs arranged about 12 or 15 feet above, as a roof to the stage, and down one side to a distance of about 3 feet from the floor, and about 12 kilowatts used in some form of arc, conveniently a flame arc about 10 feet in front of the stage and the same distance from the floor. Such an arrangement is typical of many of the stages used by the large producers of moving pictures in this country, and the importance of artificial illumination in this work can be realized when it is understood that many producers will have six such stages working at one time.

Concerning Aluminum Pistons. ANON. (*The Horseless Age,* vol. xxxvi, No. 9, October, 1915.)—It is sometimes argued that, since aluminum has a very much higher heat conductivity than cast iron, an aluminum piston will not get nearly as hot as a cast-iron piston under similar service, and that consequently, although the coefficient of expansion of aluminum is much greater than that of cast iron, not much more clearance between piston and cylinder need be allowed with aluminum pistons than with the old kind. Extended experience, however, shows that this theory is entirely wrong. It does not seem logical that an increase in the heat conductivity of the piston material should make any important difference in its temperature, because any slight reduction of the temperature of the piston head would result in a corresponding increase in the temperature difference between the burning charge and the piston and in greater heat absorption by the piston. Moreover, the dissipation of the heat absorbed by the piston depends much more on the low conductivity of the oil film separating piston and cylinder wall than upon the conductivity of the piston material. Hence it seems reasonable to suppose that the working temperature of the aluminum piston will be substantially the same as that of a cast-iron piston, and that the clearance allowances must be nearly in proportion to the coefficients of expansion of the two metals, not absolutely, because the piston must not become an absolute fit in the cylinder at working temperature, as then there would be no room left for the oil.

One objection sometimes raised against aluminum alloy pistons is that the rings are harder than the metal of the grooves in which they fit, and that consequently the grooves soon wear. Whatever the explanation may be, experience here again is said to show that the rings wear before the groove.

THE FRANKLIN INSTITUTE

(*Proceedings of the Stated Meeting held Wednesday, October 20, 1915.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 20, 1915.

VICE-PRESIDENT JAMES M. DODGE *in the Chair.*

Additions to membership since last report, 14.

Mr. George H. Clamer, chairman of the Committee on Science and the Arts, reported the condition of the committee's work.

A communication from the Alumni Association was read advising the Institute of the election of Mr. Edward V. McCaffrey to the Board of Managers as the representative of the Association for a period of three years, beginning January, 1916.

Mr. George H. Clamer, chairman of the Committee on Science and the Arts, introduced Mr. John C. Wahl, of Chicago, Ill., inventor of the Wahl Calculating Attachment for Typewriters, who had recently been awarded the John Scott Legacy Medal and Premium by the City of Philadelphia, on the recommendation of The Franklin Institute, for his invention, and Mr. George W. Dickerman, representing the manufacturers of this device, to whom had been awarded the Edward Longstreth Medal of Merit for the methods and means of its commercial production, and described briefly the invention of Mr. Wahl. The medals were presented to Messrs. Wahl and Dickerman by the President.

Dr. Heinrich O. Hofman, Professor of Metallurgy, Massachusetts Institute of Technology, presented a communication, entitled "Recent Progress in the Metallurgy of Copper." The speaker discussed the great changes which have taken place in this country during the last ten years in the treatment of sulphide copper ore and the fire-refining of copper. In blast-furnace practice the former roasting and reduction process has been almost wholly replaced by some form of pyritic smelting. Smelting in the reverberatory furnace, which was of secondary importance, has been so improved that it is competing to-day with blast-furnace work. In bringing forward copper matte to metallic copper the reverberatory furnace has become obsolete; the pneumatic process of Manhès, which caused this radical change, uses an acid-lined vessel; this has been superseded by the neutral or basic lining. While important progress has been made in the refining of copper, the improvements in the methods are not so radical as those in the treatment of ores. The subject was illustrated by specimens and lantern slides.

After brief discussion the thanks of the meeting were extended to Dr. Hofman by a rising vote.

Adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, October 6, 1915.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 6, 1915.

MR. G. H. CLAMER *in the Chair.*

The following report was presented for first reading:
No. 2617.—Permutit.

The following report was referred back to the subcommittee for reconsideration:
No. 2636.—Lenker's L-E-Vation Rod.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A stated meeting of the Section was held in the Hall of the Institute on Thursday, October 7, 1915, at 8 o'clock P.M., with Dr. Gellert Alleman in the chair. Two hundred and fifteen members and visitors were present. The minutes of the previous meeting were approved as read.

Benjamin T. Brooks, Ph.D., of the Mellon Institute of Industrial Research, University of Pittsburgh, delivered a lecture on "The Decomposition of Petroleum Hydrocarbons by Heat and its Application to the Motor Fuel Problem." Brief consideration was given to the relative importance of gasoline substitutes. The decomposition of complex petroleum hydrocarbons by heat, the effect of heat and pressure upon unsaturated hydrocarbons, the use of catalysts in the preparation of gasoline, and the effect of various factors in the deterioration of gasoline were discussed. Special reference was made to methods which have been proved capable of successful large-scale operation. The lecture was illustrated with lantern slides and experiments. After a discussion, a vote of thanks was extended to the speaker and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A stated meeting of the Section was held in the Hall of the Institute on Thursday, October 14, 1915, at 8 o'clock P.M., with Dr. Henry H. Donaldson in the chair. The minutes of the previous meeting were read and approved.

Dr. Ulric Dahlgren, Professor of Biology in Princeton University, delivered an address on "Production of Electricity by Animals." The general presence of minute electric discharges in all vital functions of protoplasm was discussed. The species of fish which contain special electric organs were enumerated; and the macroscopic and microscopic structure of these organs and their operating nerve apparatus were described. The development of the electric organs from striated muscle was traced, and their physiology and uses were reviewed. The lecture was illustrated with lantern slides and with specimens of fish. The meeting extended a vote of thanks to Dr. Dahlgren, and then adjourned.

JOSEPH S. HEPBURN,
Secretary.

MINUTE OF THE BOARD OF MANAGERS ON THE DEATH OF JOHN T. MORRIS.

(*Meeting of October 13, 1915.*)

John Thompson Morris, President of the Board of Trustees of The Franklin Institute, and for many years its friend and benefactor, died on August 15, 1915.

The members of the Board of Managers unite with the remaining members of the Board of Trustees in expressing their sense of the deep loss which the Institute has thus suffered, and their gratitude for the devotion which Mr. Morris gave to its interests.

He became a life member of The Franklin Institute in 1880, and when the Board of Trustees was created in 1888 he was appointed to be one of its original members. He was elected president of the Board of Trustees on March 20, 1905, and served in that capacity until the time of his death, always watchful of the trust committed to his hands, and zealous towards ensuring its fulfilment. No detail was so small as to be ignored by him, and no trouble too great to be met by his painstaking care.

In addition to the services thus contributed, Mr. Morris gave to the Institute the sum of $5000, to be employed as a Library Fund, the income to be devoted to the purchase of books on mechanical subjects, this gift being a memorial to his brother, James T. Morris.

Apart, however, from the material side of his connection with the Institute, Mr. Morris brought to its meetings and councils sympathy, intelligence, and brightness.

Thoroughly educated at the start of his career, and trained in experience of men and affairs by his business life, his release from the more arduous duties of business enabled him to expand his knowledge by wide travel and to gratify to the utmost his interest in art.

Those who were privileged to enjoy his personal friendship and share in his hospitality will long remember the keen pleasure which he took in literature, music and the fine arts, and the quiet dignity of his home life, surrounded by the carefully-selected acquisitions of his artistic tastes.

In his later years his interest turned especially towards trees and flowers, but notwithstanding his intimacy with the science that relates to these subjects, one could not fail to observe that his real motive was the love of a tender and gentle nature for the spirit of the woods and of the garden.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, October 13, 1915.*)

RESIDENT.

Mr. Carl P. Birkinbine, Parkway Building, Philadelphia, Pa.
Dr. Jacob S. Goldbaum, 212 West Winona Avenue, Norwood Station, Pa.
Mr. J. Rogers Holcomb, 29 West Tulpehocken Street, Germantown, Philadelphia, Pa.

NON-RESIDENT.

Mr. E. Z. Crow, care of American Trust and Savings Bank, Birmingham, Ala.
Mr. Leonard Kebler, care of Ward Leonard Electric Company, Bronxville, N. Y.
Mr. James Lyman, 1412 Edison Building, Chicago, Ill.

LIFE.

Mr. Thomas W. Elkinton, care of Philadelphia Quartz Company, 121 South Third Street, Philadelphia, Pa.

ASSOCIATE.

Mr. Frederick Denig, 2244 Thirteenth Street, Troy, N. Y.

CHANGES OF ADDRESS.

Prof. James Barnes, Bryn Mawr College, Bryn Mawr, Pa.
Mr. Herbert S. Berliner, Box 5, St. Henry, Montreal, Quebec.
Mr. Gideon Boericke, Wynnewood, Pa.
Mr. William C. Carnell, 1108 South Forty-sixth Street, Philadelphia, Pa.
Mr. Edward L. Coster, Katonah, N. Y.
Mr. Francis X. Daily, 116 Walnut Avenue, Ardmore, Pa.
Mr. Frederic A. Delano, 294 Treasury Building, Washington, D. C.
Mr. Paul Didier, Conestoga Building, Wood and Water Streets, Pittsburgh, Pa.
Mr. John Uri Lloyd, Clifton and Lafayette Avenues, Cincinnati, Ohio.
Mr. W. E. Moore, Room 705, Union Bank Building, Pittsburgh, Pa.
Prof. I. M. Rapp, 321 West Symmes Street, Norman, Okla.
Prof. Joseph P. Remington, 1832 Pine Street, Philadelphia, Pa.
Mr. J. A. L. Waddell, Waddell & Son, Consulting Engineers, 800 Graphic Arts Building, Kansas City, Mo.
Mr. Fred H. Wagner, Rogers Avenue and Pimlico Road, Station " E," Baltimore Md.
Mr. Henry Wharton, Chestnut Hill, Philadelphia, Pa.
Mr. J. Clifford Wilson, 242 South Thirteenth Street, Philadelphia, Pa.
Mr. C. H. Zehnder, Room 1648, 120 Broadway, New York, N. Y.

NECROLOGY.

Morris G. Condon, 1025 Hamilton Street, Philadelphia, Pa.
H. Ward Leonard, Lawrence Park, Bronxville, N. Y.
C. L. Matthews, 503 Carpenter Street, Germantown, Philadelphia, Pa.
R. P. Stout, 404 Market Street, Bethlehem, Pa.
Nathan A. Taylor, Mariner and Merchant Building, Philadelphia Pa.

LIBRARY NOTES.

ABSTRACT OF MINUTES OF THE COMMITTEE ON LIBRARY, MEETING OF SEPTEMBER 7, 1915.

The Chairman announced the death of Mr. John T. Morris, founder of the James T. Morris Memorial Fund, and Mr. Richard Gilpin, for many years a member of the committee.

On motion it was resolved

That the Committee on Library record its deep regrets at the death of these two gentlemen, the first who by his liberality established the James T. Morris Memorial Fund for the purchase of mechanical books, and the second who by long and efficient service contributed greatly to the committee's successful work.

PURCHASES.

American Electrochemical Society.—Transactions, vol. 27. 1915.
Baker, I. O.—Treatise on Roads and Pavements. 1914.
Child, C. D.—Electric Arcs. 1913.
Curtin, R. I., and Johnson, T. L.—Naval Ordnance. 1915.
Gorgas, William C.—Sanitation in Panama. 1915.
Koller, Theodor.—Utilization of Waste Products. 1915.
Macnutt, J. S.—Manual for Health Officers. 1915.
Macomber, Ben.—The Jewel City: Panama-Pacific International Exposition. 1915.
Stein, M. F.—Water Purification Works and their Operations. 1915.
Swingle, Calvin F.—Oxy-acetylene Welding and Cutting. 1915.
Whipple, George C.—The Microscopy of Drinking Water. 1914.
White, Charles H.—Methods in Metallurgical Analysis. 1915.
Woodman, A. G., and Norton, J. F.—Air, Water and Food. 1914.

GIFTS.

American Society of Agricultural Engineers, Eighth Annual Report. Madison, Wis., 1914. (From the Society.)
American Society of Mechanical Engineers, Transactions, 1914, vol. 36. New York, 1915. (From the Society.)
Association for the Prevention of Tuberculosis of the District of Columbia. Washington Health Rules. Washington, 1915. (From Mr. Emile Berliner.)

Association of Railway Electrical Engineers, Proceedings, vols. 1 to 7. Chicago, 1908–1914. (From Mr. Jos. A. Andreucetti, Secretary.)

Atchison, Topeka and Santa Fé Railway Company, Twentieth Annual Report, 1915. (From Mr. E. P. Ripley, President.)

Basin, J., Leçon de Chimie. Paris, 1901. (From Mr. N. W. Akimoff.)

Bornsen, Paul, Radium in the Light of Recent Discovery. Washington, 1915. (From the Author.)

Boston and Maine Railroad, Eighty-second Annual Report. Boston, 1915. (From the Company.)

Canada Department of Mines, Memoir 36, Geology of the Victoria and Sannich Map-Areas, Vancouver Island, B. C.; Memoir 67, The Yukon-Alaska International Boundary, between Porcupine and Yukon Rivers; Memoir 68, A Geological Reconnaissance between Golden and Kamloops, B. C., along the Canadian Pacific Railway; Memoir 78, Wabana Iron Ore of Newfoundland, The Salt Deposits of Canada, and The Salt Industry. Ottawa, 1913–1915. (From the Department.)

Carnegie Endowment for International Peace, Year Book, 1915. Washington, no date. (From the Endowment.)

Carrier Air Conditioning Company of America, Catalogue No. 13 of Carrier Air Washers and Humidifiers. New York, no date. (From the Buffalo Forge Company.)

Cleveland Engineering Society, Annual Register. Cleveland, 1915. (From the Society.)

Comision Protectora de Bibliotecas Populares, Anales de la Biblioteca, Tomo ix. Buenos Aires, 1914. (From the Comision.)

Commissioner of Patents, Annual Report, 1914. Washington, 1915. (From the Commissioner.)

Dalby, H. A., Train Rules and Train Dispatching. New York, 1904. (From Robert D. Jenks, Esq.)

Denver and Rio Grande Railroad Company, Twenty-ninth Annual Report. Denver, 1915. (From Mr. E. R. Murphy.)

Fall River Water Works, Report of the Watuppa Water Board. Fall River, Mass., 1915. (From the Water Works.)

1 inlande l'Administration générale de l'industrie, Teollisuushallituksen Tiedonantoja, Meddelanden fran Industristyrelsen I Findland. Helsingfors, 1915. (From the Administration Generale.)

Hirsch, M., Die Luftpumpen, parts i and ii. Hanover, 1905. (From Mr. N. W. Akimoff.)

Illinois Society of Engineers and Surveyors, Incorporated, Thirtieth Annual Report, 1915. Wheaton, no date. (From the Society.)

International High Speed Steel Company, Catalogue of Mining and Rock Drill Steel. New York, no date. (From the Company.)

International Library of Technology, vols. 73 and 74. Scranton, Pa., no date. (From Mr. N. W. Akimoff.)

International Railway Fuel Association, Proceedings, 1911–1915. Chicago, 1911–15. (From Mr. C. G. Hall, Secretary.)

Iron and Steel Institute, Journal, No. 1, vol. xci. London, 1915. (From the Institute.)

Leland Stanford Junior University, Register, 1914–15. Stanford University, Calif., 1915. (From the University.)

Link-Belt Company, General Catalogue No. 110. Philadelphia, no date. (From the Company.)

Madison Water Commission, Thirty-second Annual Report, 1914. Madison, Wis., 1915. (From the Commission.)

Marchena, R. E. de, Machine Frigorifiques. Paris, no date. (From Mr. N. W. Akimoff.)

Medart Patent Pulley Company, Catalogue of Power Transmitting Appliances. St. Louis, no date. (From the Company.)

Metropolitan Water and Sewerage Board, Fourteenth Annual Report, 1914. Boston, 1915. (From the Board.)

Michigan College of Mines, Year Book, 1914–15. Houghton, no date. (From the College.)

Minneapolis, St. Paul and Sault Ste. Marie Railway Company, Twenty-seventh Annual Report. Minneapolis, 1915. (From the Company.)

Missouri Botanical Garden, Annals, vol. ii, No. 3. Missouri, 1915. (From the Trustees of the Botanical Garden.)

Musil, A., Die Motoren für Gewerbe und Industrie, und Wärmemotoren. Braunschweig, 1897 and 1899. (From Mr. N. W. Akimoff.)

New York, Ontario and Western Railway Company, Thirty-sixth Annual Report. New York, 1915. (From the Company.)

New York University, Theses: The Genesis of Certain Paleozoic Interbedded Iron Ore Deposits, by Raymond B. Earle; A Dissertation on the Development of the Science of Mechanics, by David H. Ray; The Densities of Certain Dilute Aqueous Solutions by a New and Precise Method, by Richard E. Lee; and five pamphlets on various subjects. New York, 1904–1914. (From the Librarian.)

New Zealand Institute, Transactions and Proceedings, vol. xlvii, 1914. Wellington, 1915. (From the Institute.)

North Carolina Geological and Economic Survey, Economic Paper No. 40, Forest Fires in North Carolina during 1914; Economic Paper No. 42, Organization of Coöperative Forest-fire Protective Areas in North Carolina. Raleigh, 1915. (From the Survey.)

North of England Institute of Mining and Mechanical Engineers, Annual Report of the Council, 1914–15. Newcastle-upon-Tyne, 1915. (From the Institute.)

Ohio University, Catalogue, 1915–16. Athens, 1915. (From the University.)

Philadelphia Bureau of Gas, Report, 1914. Philadelphia, no date. (From Mr. Judson C. Dickerman, Chief.)

Ruud Manufacturing Company, Handbook of Gas Water Heaters. Pittsburgh, 1915. (From the Company.)

Seydel's Führer durch die neuere deutsche technische Litteratur. Berlin, 1898. (From Mr. N. W. Akimoff.)

Standard Machinery Company, Catalogues of Rolling Mills, Drop Presses, Power Press and Miscellaneous Machinery. Providence, R. I., no date. (From the Company.)

State College of Washington, Catalogue. Olympia, 1915. (From the College.)

Sturtevant, B. F., Company, Catalogue No. 215, Heating and Ventilation. Boston, no date. (From the Company.)

Tufts College, Catalogues, 1901 to 1915. Tufts College, Mass., no date. (From the College.)

Tulane University of Louisiana, Registers, 1911 to 1915. New Orleans, La., no date. (From the University.)

Union Chain and Manufacturing Company, Catalogue No. 3 of Steel Chains. Seville, Ohio, no date. (From the Company.)

U. S. Army, Index Catalogue of the Library of the Surgeon-General's Office, vol. xx, Second Series. Washington, 1915. (From the Surgeon-General's Office.)

Universal Portland Cement Company, Concrete for the Farmer; Concrete in the Barnyard; Concrete Pavements, Sidewalks, Curb and Gutter; Concrete Silos; Small Farm Buildings of Concrete; Concreting in Cold Weather; Small Concrete Bridges and Culverts; Proceedings of Conference on Permanent and Sanitary Farm Improvements; Concrete Surfaces; Farm Cement News. Chicago, 1913–14. (From the Company.)

University of Illinois, Register, 1914–15. Urbana, no date. (From the University.)

University of Pittsburgh, Catalogue, 1914–15. Pittsburgh, 1915. (From the University.)

University of Utah, Catalogue, 1914–15. Salt Lake City, no date. (From the University.)

University of Wisconsin, Catalogues, 1913–14, 1914–15. Madison, 1914, 1915. (From the University.)

Uruguay Anuario Estadistico, vol. xxiii, 1911 and 1912. Montevideo, 1915. (From the Director General de la Statistique.)

Weinstein, B., Thermodynamik und Kinetik der Körper. Braunschweig, 1901. (From Mr. N. W. Akimoff.)

BOOK NOTICES.

Surface Tension and Surface Energy, by E. S. Willows and E. Hatschek. Philadelphia, P. Blakiston's Son & Company, 1915. 80 pages, illustrations. Price, $1.

Many years ago the great Belgian chemist, Prof. W. Spring, of Liège, who had a rare talent for obtaining unexpected and important results by very simple experiments, found that when a crystal of calcite is partially immersed in hydrochloric acid the action is most rapid at the surface, so that the crystal is cut in two pieces. The same thing occurred when a sugar crystal was suspended in water. Since these early observations, facts which demonstrate that the surface of a liquid may, under proper conditions, behave in a different manner from the interior have accumulated. Solutions are now known in which practically the whole of the solute accumulates in the surface film. This, in very dilute solution, is the case with such familiar substances as salicylic acid and the soaps.

Striking facts like these, whose interest to the chemist, the physicist, and the biologist is obvious, furnish a sufficient reason for a simple and intelligible treatment of the difficult subject of surface energy. However, from a somewhat different point of view the book is welcome. The scientific and practical importance of the colloidal state is increasing at a wonderful rate. We consist of colloids, exist by consuming them, and nowadays almost everybody wants to have them explained to him. But a colloid system may be roughly defined as a state in which subdivision has gone so far that surface energy has assumed the chief rôle and has relegated gravitation, cohesion, etc., to the background, so that the book has an intimate connection with the subject of colloids, though it does not avowedly treat of them.

The reviewer has nothing but commendation for this little volume. Clearness and accuracy prevail throughout. The treatment is almost non-mathematical, and the chemists, for whom it seems to be intended, will be able to use it without much difficulty and to great advantage.

ROBERT H. BRADBURY.

U. S. BUREAU OF MINES BULLETIN 94. United States Mining Statutes Annotated by J. W. Thompson. Part I, Sections and Statutes Relating to Metalliferous and Coal Mining. Part II, Miscellaneous Mining Subjects. Two volumes, 8vo. Washington, Government Printing Office, 1915. Price $2.50.

The Bulletin is intended for persons engaged in mining enterprises that come within the scope of the Federal mining laws, and as a guide in the determination of mining rights and duties. It shows the status of every Federal law relating to mining, those relating to metal mining as well as those relating to coal, oil and phosphate, and to mining on public, Indian, and railroad lands. The work includes also references to Alaska and the Philippine Islands.

PUBLICATIONS RECEIVED.

U. S. Bureau of Standards: Technologic Paper, No. 48, An Air Analyzer for Determining the Fineness of Cement, by J. C. Pearson, Assistant Physicist, and W. H. Sligh, Aid, Bureau of Standards. 74 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1915.

U. S. Bureau of Mines: Bulletin 75, Rules and Regulations for Metal Mines, by W. R. Ingalls, James Douglas, J. F. Finlay, J. Parke Channing, and John Hays Hammond. 296 pages, 8vo. Bulletin 101, Law Serial 5, Abstracts of Current Decisions on Mines and Mining, October, 1914, to April, 1915, by J. W. Thompson. 138 pages, 8vo. Monthly Statement on Coal-mine Fatalities in the United States, July, 1915, compiled by Albert H. Fay. 16 pages, 8vo. Washington, Government Printing Office, 1915.

Eastman Kodak Company: Abridged Scientific Publications from the Research Laboratory, 1913–1914. 76 pages, illustrations, 8vo. Rochester, N. Y., Eastman Kodak Company, no date.

New York Public Library: New Technical Books. A Selected List on Industrial Arts and Engineering Added to the New York Public Library, June to August, 1915. 28 pages, 8vo. New York, N. Y., Public Library, 1915.

U. S. Department of Agriculture: Bulletin 284, Construction and Maintenance of Roads and Bridges from July 1, 1913, to December 31, 1914. 64 pages, 8vo. Washington, Government Printing Office, 1915.

Potts, Rufus M.: Protecting Congested Districts in Cities. Address delivered by Rufus M. Potts, Insurance Superintendent of Illinois, before the National Convention of Insurance Commissioners, Monterey, Calif., September 22, 1915. 9 pages, 8vo. Springfield, Ills., State Printers, 1915.

Cooling Ponds for Condensing Engines. L. H. PARKER. (*Proceedings of The National Association of Cotton Manufacturers,* September 9 to 11, 1915.)—Spray cooling pond systems under average conditions have lowered first cost, require less power for operation and practically no maintenance as compared with cooling towers, and they are being used to a constantly increasing extent in connection with cotton mills, except in cases when sufficient pond area is not available, either on the ground or on the roofs of buildings adjacent to the condensing installation.

Some mills of comparatively small capacity are now operated non-condensing, due to the lack of a sufficient supply of cool water. Many of these mills could install an earthen pond or a concrete basin at small expense and thus make a net saving in power cost of 15 to 20 per cent.

In addition to a number of other economic advantages, the first cost of spray systems including ponds generally averages one-half the cost of cooling towers of similar capacity and of good design and construction.

Slush Castings. G. RIGG and H. C. MORSE. (*Proceedings of the American Institute of Metals,* September 28 to October 1, 1915.)—The process of slush casting is used quite extensively in the manufacture of various ornamental objects. Hollow and therefore relatively light castings are produced by pouring the metal into the mould until full and immediately pouring out again what remains liquid, leaving a thin-walled casting chilled upon its inside surface. The mould is usually mounted upon trunnions or otherwise arranged to facilitate its rapid emptying. The moulds are of metal, usually bronze or brass, which can be machined easily and will not be injured by the molten metal. Zinc with small percentages of impurities, commonly cadmium, lead, iron, and arsenic, known as spelter, is employed for the castings.

CURRENT TOPICS.

The Difficulties of Color Cinematography. Anon. (*British Journal of Photography,* vol. lxii, No. 2891, October 1, 1915.)—It is obvious that the most satisfactory solution of the problem of producing films in color would be one in which the colors exist in the film itself, as they do in screen plates or in transparencies formed by some process akin to three-color carbon. Screen-plate methods, however, present almost insuperable difficulties when applied to cinematograph films. To say nothing of the cost, which is a very serious item, there are great troubles due to the extreme delicacy and fragility of all such screen films, and also inventors have to cope with the enormous magnification to which cinematograph pictures are subjected that renders anything but a screen of the finest possible grain almost useless. Lack of sufficient transparency is also a trouble, and a prohibitive one in the case of screens that approach the density of the Autochrome. Methods akin to the three-color carbon process also present great difficulties, even if we reduce the three colors to two. In addition to the technical difficulties of printing such films, we have a new trouble of securing two or three separate negatives. The same trouble exists when we attempt to apply the additive three-color projection process or a two-color equivalent, such as the "Kinematicolor," and this trouble is due to the effects of parallax, which must exist if the several negatives are not produced at the same instant and from exactly the same standpoint.

In ordinary three-color photography this difficulty has necessitated the invention of what are called one-exposure cameras, in which one lens is used and the light transmitted by it is split up by mirrors, so that three separate images are simultaneously produced, each through its own color screen. Such cameras require very delicate adjustment, and a cinematograph designed on the same principles would be both delicate and complex. Moreover, the splitting up of the light by reflectors lowers its intensity on each image.

The only method that is in practical use at the present time is "Kinematicolor," a two-color method, with which persistence of vision is relied upon for the visual combination of alternate images projected in red and green respectively. In this method the different phases of movement represented by the different images prevent perfect combination when the movement depicted is a rapid one, but the process gives excellent results so long as the movement is not too rapid. Though the method is only a compromise and not an ideal solution of the problem, its popular success shows that a perfect solution is quite worth while achieving.

Experiments with Natural and Illuminating Gas. (*Technical Paper No. 104, United States Bureau of Mines.*)—This publication is one of a series dealing with the increase in efficiency in the production and utilization of fuels. Fractional distillation in a vacuum at low temperatures is employed in the experiments. The gas is liquefied, the different constituents separated by proper adjustment of temperature, the various fractions removed with a mercury pump and these fractions analyzed by ordinary slow-combustion methods. The method was successfully applied to the separation of hydrocarbons in natural gas and in artificial illuminating gas, and is the only known method applicable to the separation of some hydrocarbons.

The first part of the report describes the results of experiments by which the natural gas used in Pittsburgh, Pa., was separated into its individual paraffin hydrocarbons. The second part describes experiments in which the separation of the illuminants in artificial illuminating gas of Pittsburgh and New York City was effected. Some experiments to determine the practicability of separating gases whose boiling-points lie close together, such as ethane and ethylene, are included.

Cutting Aluminum Rapidly on a Buzz Planer. ANON. (*American Machinist*, vol. 43, No. 16, October 14, 1915.)—One of the most striking innovations seen in a machine shop in many years is the use of a buzz planer for surfacing the aluminum oil pans which go under the engine crank case of a Curtis aëroplane motor. This was done in the shop of the Herschell-Spillman Company, North Tonawanda, N. Y., not simply as a revolutionary innovation, but to solve a problem not easily met in any other way.

There were 150 crank cases or oil pans to surface, and the walls were only ⅛ inch thick—very light to hold in an ordinary fixture so as to withstand the stresses of cutting and clamping without distortion. So the buzz planer was tried and with excellent results.

Although it required from six to eight cuts to remove the 1/16-inch metal necessary, the average time for each casting was less than 10 minutes. This and the saving of expense for fixtures made it a low-cost operation.

The entire 150 pans were surfaced in this way, the regular buzz-planer knives surfacing an average of 35 oil pans between each sharpening of the knives, which left a good surface on the pans.

Aluminum has offered opportunities for many experiments in high-speed cutting, the limiting factor often being the ability to hold the work and resist the cutting stress without distortion. In a number of cases 150 feet cutting speed for aluminum is being regularly used, and, while this has by no means been considered the limit of the cutting tool, other factors have seemed to make it the practical limit. It does not seem impossible that a modification of the high speed and light cut of the buzz planer may yet be made to apply to the harder substances.

Many Carbon-free Metals and Alloys Now Available. H. DEC. BROWNE. (*Engineering News,* vol. 74, No. 14, September 30, 1915.)—Manganese, chromium, and cobalt 97 to 99 per cent. pure, and carbon-free alloys of these and other elements, such as vanadium and titanium, are now readily procurable. In many metallurgical operations there is need of employing carbon-free metals and alloys in order to control fully the physical properties of the final metal, which may be a special steel or bronze, for instance. A large number of these have been developed by the Goldschmidt Thermit Company of New York City, employing in their production the well-known aluminum-oxidation reaction by which a high temperature is produced in carbon-free surroundings.

A Possible Substitute for Acetylene in Welding and Cutting. J. F. SPRINGER. (*Railway Age Gazette,* Mechanical Edition, vol. 89, No. 10, October, 1915.)—Ordinary natural gas consists largely of methane, the heating value of which is low in comparison with acetylene. At Follansbee, W. Va., a natural gas is produced which contains no methane and is made up of approximately four-fifths propane and one-fifth ethane. This gas has a thermal value of 2468 B. T. U. per cubic foot. Experiments with this gas at various stages of compression indicate that the constituents of higher thermal value are first liquefied, leaving the others in the residual gas. When subjected to 400 pounds pressure per square inch at 32° F., and re-vaporized, a gas of varying quality was obtained. Of several samples taken at regular intervals, one was almost pure ethane, another almost pure propane. The lowest thermal value was 1808 B. T. U., and the highest, 2621 B. T. U. per cubic foot. The methane which has the lowest heating value (1065 B. T. U.), and is therefore the least desirable in the semi-liquid product, requires a pressure of 2700 pounds per square inch to cause it to liquefy, and is therefore not apt to be present in the product of compression under 400 pounds per square inch.

From another set of experiments with Follansbee gas under 400 pounds pressure, it was found that samples drawn from the top of the same cylinder varied considerably in quality and heating value. It was found, however, that by drawing the supply for the torch from the bottom a gas of approximately uniform quality may be obtained. Its boiling-point is –40° F., and at 32° F. it requires a pressure of 400 pounds to maintain it in a liquid state. At 131° the pressure is 755 pounds, which is well within the practice of handling similar products. If higher temperatures are apt to be met it will not be difficult to secure containers to withstand the higher pressure.

The new gas seems to have originated through the development of natural gas gasoline, which was first obtained by simply collecting the liquid formed by condensation in pipes transmitting natural gas. The next step was artificial chilling of the pipes, followed by low-pressure, single-stage compression, and later of carrying the raw gas through two stages of compression.

A Novel Design in Gas Holders. ANON. (*The Times* (London) *Engineering Supplement,* No. 491,September 24, 1915.)—Since the early days of gas lighting the floating bell or "balloon" principle has without exception been adopted in the design of gas holders, although various schemes for the guidance of the bell during its upward and downward travel have from time to time been introduced. Perhaps the most striking departure from the stereotyped design was witnessed with the spiral holder, in which separate guide framing was discarded altogether. So far as originality is concerned, however, the new "floating roof" holder (hailing from Nuremberg) demands a certain amount of attention.

The principle employed permits the expensive water tank (always associated with the common type of holder) to be dispensed with altogether, although gas-tightness is insured by the use of water seals as heretofore. Simply explained, the holder consists of an outer cylindrical shell very similar in construction and appearance to the present holder bell, but with the exception that no movement is permitted. The contrivance is, in fact, little more than a cylindrical tank, the roof of which, by means of guide rollers, is permitted to rise and fall within the tank. Gas is admitted in the ordinary way beneath the roof, which ascends and descends in accordance with the prevailing pressures in the interior. The guidance of the floating dome is such that the smallest amount of clearance is permitted between it and the internal periphery of the cylinder: hence the space available for gas escape is reduced to a minimum. The means employed for the prevention of all leakage is, however, novel, and consists in pumping water upon the exterior of the dome so that it runs down to the portions above the guide rollers and seals up the clearance between cylinder and dome. Some portion of the water is, of course, continuously passing through this clearance into the interior of the holder, whence it is removed by way of a seal and returned to the suction of the pump. The last-named is so regulated that the quantity of water delivered to the exerior of the crown is just sufficient to replace the wastage into the interior. Thus the flexible but gas-light joint is constantly maintained.

So far as capital outlay is concerned, the new holder possesses undoubted advantages and, providing no difficulties are met with in practice, should prove of especial utility in the smaller works. A feature that must not be overlooked, moreover, is the readiness with which the pressure may be adjusted by regulating the quantity of water carried by the crown.

New Krupp Armor Plates. ANON. (*Scientific American,* vol. cxiii, No. 16, October 16, 1915.)—During the past year the Krupp works at Essen have perfected a new kind of armor plate that has a far greater power to resist the penetration of projectiles than any heretofore produced. But, although these plates are extremely valuable for the protection of ships of war, a wide application is anticipated for them in the building of safes. Not only are the plates so extremely hard that they cannot be drilled, but they have a remarkable resistance to the flame of an oxyacetylene lamp. It is estimated that to burn a hole three inches in diameter and ¾ inch thick would require six hours and the consumption of 350 cubic feet of oxygen and 320 cubic feet of acetylene.

Recent Developments in Light Signal for Control of High-speed Traffic. J. E. SAUNDERS. (*The Electric Journal,* vol. xii, No. 10, October, 1915.)—The most recent development in light signalling is the position light signal now in operation on the Pennsylvania Railroad between Broad Street Station, Philadelphia, and Paoli, Pa. The basic principle embodied in the development of this signal is that indication both by day and by night shall be independent of color. Indications by this signal are given by the illumination of any one of three rows of lamps extending either horizontally, at an angle of 45 degrees, or vertically. The minimum daylight range is approximately 3000 feet.

Probably the first twenty-four-hour light signal had a daylight range of one hundred feet or less and was used for the control of a trolley car. About two years ago experiments were conducted in the laboratories of the Union Switch and Signal Company to determine the value of the application of concentrated filament lamps to light signals. Very quickly the range of 500 feet in 1910 became 2000 feet, and, with further improvements in lens arrangement, minimum daylight ranges of 3000 feet were made possible. At the same time the voltage of the lamps was steadily reduced until at the present time signal indications are conveyed in bright sunlight with an expenditure of only 20 watts.

Tests of Lenses for Foundry Goggles. F. W. KING. (*Proceedings American Foundrymen's Association,* September 28 to October 1, 1915.)—To meet the requirements for goggles in foundry operations provided with lenses that will not shatter when struck, manufacturers have developed optical glass that not only meets the most rigid specifications, but which will withstand a more severe test than that prescribed by any user. The Illinois Steel Company has designed a drop-test machine for testing lenses which is equipped with a support for the goggles. A steel ball ⅝ inch in diameter, weighing 16.25 grammes, is dropped from a height of 21 inches upon the lens, which must withstand 15 blows without breaking or cracking. From a shipment of a gross or more of goggles, 25 per cent. of one dozen are selected at random for this test. If any of the six lenses fails in the test, the entire shipment is rejected.

A lens has been developed which can successfully withstand the impact of a 9-ounce ball, 1½ inches in diameter, as compared with the 1-ounce ball specified.

Artificial Daylight for the Microscope. S. H. GAGE. (*Science,* vol. xlii, No. 1085, October 15, 1915.)—Until very recently all the efforts to make a light filter or screen for artificial light which would transmit light having daylight qualities by which colors could be detected and discriminated with the same certainty as in daylight were unsuccessful.

During the last two years Dr. Henry Phelps Gage, working in the laboratories of the Corning Glass Works, with the facilities there found, has developed a glass filter which renders the light from a nitrogen-filled tungsten lamp almost exactly like daylight. The light approaches very closely that of sunlight, especially in the region of the visible spectrum giving the greatest amount of useful light.

Light filtered through the daylight glass has been very critically tested on microscopic objects stained with many different dyes. The tests were made in the daytime by a window so that it was possible to turn the mirror from artificial daylight to true daylight instantly. In the hands of several observers no differences in color could be detected in all the tests made with varied subjects.

The glass was tested with other light sources used in microscopic work, viz., the vacuum tungsten and carbon filament lamps, illuminating gas with Welsbach mantle, acetylene, and, finally, the flat-wick kerosene lamp. None of these other sources gave exactly the same color values as daylight. However, the approximation to daylight was surprisingly good, and the worst one, the kerosene flame, gave better color values than the best artificial light without the color screen.

The Development of the Army Pistol. E. C. CROSSMAN. (*Scientific American,* vol. cxiii, No. 14, October 2, 1915.)—The main function of a pistol in warfare is to immediately dispose of an antagonist before he can harm the possessor of the weapon. It is far better to eliminate the foe as a fighting force, even temporarily, than to inflict a fatal wound—fatal hours later, but not immediately disabling. Time is the essential feature; it is what the other man does the first ten seconds after being hit that determines whether or not the arm is an efficient arm. All this because the range is no longer in inches than the ordinary range of the rifle fight is in yards.

Owing to the absolute necessity of immediately eliminating the foe—delivering a crumpling blow of the bullet on one who may be threatening the possessor of the pistol with almost certain death—the United States Government has adopted the 0.45 calibre with a ponderous 230-grain bullet. The velocity is but 800 feet per second, less than a third that of the army rifle, while the bullet weighs 50 per cent. more than that of the rifle. Range, trajectory, remaining energy at a mile, none of these things count when the mark is but a few feet away.

Those nations that have carried on warfare with savages fully appreciate the value of large calibred pistols. The British, after various encounters with the hill men of India, evolved a generous bullet of 0.455 calibre for their service revolvers. Their officers went even further and adopted a double-barrelled pistol taking either huge slugs or a number of buckshot. These pistols were usually of 20-gauge in shotgun measurement, which in inches is 0.615 calibre, smooth bored. These huge 0.61 slugs usually proved amply effective in use.

The United States Army discarded the old, single-action, 0.45-calibre revolver in the '90's and adopted a 0.38-calibre, double-action revolver. Then came the conquest of the Filipino insurgents, in which the revolver as a weapon was largely employed. The experience of the American soldiers engaged was precisely that of the British; namely, the larger the calibre, the better the results, and the 0.38-calibre was voted ineffective. So there is considerable satisfaction with the present gun of the American forces, the 0.45-calibre automatic Browning pistol, with its eight shots, its compact form, ease of taking apart, and certainty of function.

The other nations lacking the practical experience of the Americans along a western frontier, and the British in their various and never-ceasing arguments along the Indian frontier, favor smaller calibres in their pistols than we regard as being practical. The 9-mm. or 0.36-calibre appeals to them as adequate. None of the nations now at war has adopted the 0.45-calibre in its automatic pistols, but doubtless they will know better when the war is over.

Gas-Electric Locomotives for "Dan Patch" Line. ANON. (*Electric Railway Journal,* vol. xlvi, No. 14, October 2, 1915.)—The Minneapolis, St. Paul, Rochester, and Dubuque Electric Traction Company, operating what is popularly known as the "Dan Patch" electric line, has recently placed in commission three 60-ton gas-electric locomotives for freight, passenger, and terminal service. This line is said to be the first railroad to be operated entirely with gas-electric service. The locomotives are double-ended, being built with the box type of cab extending nearly the entire length of the underframe. The wheels are 33 inches in diameter, and each locomotive is equipped with four 100-h. p. motors.

Each of the two gas-electric generating sets for the power plant equipment is composed of a 175-h. p., 550-r. p. m., 8-cylinder, 4-cycle gasoline engine of the "V" type which is direct-connected to a 600-volt, commutating pole, compound wound electric generator. The cylinders are 8 inches bore and 10 inches stroke. Ignition is accomplished with low-tension magnetos, and the sets are started by air-pressure in the same way as in the gas-electric motor cars, with the additional feature that when one set is running, the other may be started electrically from the first. The control is so arranged that either one or both of the generating units may be used to operate the locomotive from either end.

Nickel-plating Aluminum. ANON. (*La Chronique Industrielle,* 38th year, No. 224, September 1, 1915.)—A process of nickel-plating aluminum, invented by M. J. Carnac, which is claimed to produce a firmly-adhering coating, is described in *Ind. e Inv.,* Barcelona.

The aluminum is first cleaned in a bath of boiling potash; it is next brushed with milk of lime and then immersed into a bath of potassium cyanide for several minutes; finally it is subjected to the action of a bath of ferrous chloride, composed of 500 grammes of hydrochloric acid, 500 grammes of water, and 1 gramme of iron. After each operation the object is washed in clear water.

Good results are obtained from a plating bath composed of water, 1000 c.c.; chloride of nickel, 50 grains; boric acid, 20 grains; with a current of 1 ampère per square decimetre at 2.5 volts. The good results of the process appear to depend upon the perfect cleaning and a suitable deposition on the aluminum of a thin coating of iron from the iron bath. The existence of this thin coating is verified by comparing with a magnetic balance a treated and an untreated specimen of aluminum.

Under these conditions the nickel deposit infiltrates through the surface of the aluminum and adheres so thoroughly to it that, however heavy the deposit, it is impossible to detach the nickel without removing particles of aluminum.

Use of a Small Cooling Tower for Transformer Circulating Water. ANON. (*Electrical World,* vol. 66, No. 15, October 9, 1915.)—The very considerable total loss of energy which takes place even in such high-efficiency apparatus as electric transformers may be well appreciated from the arrangement of the water-cooling service for the transformer at a new sub-station of the East St. Louis Light and Power Company. The practice at this station is that of cooling and recirculating the transformer cooling water in a miniature cooling tower. Water is pumped through two large transformers at the rate of about 100 gallons per minute by a 5-horsepower motor. The fact that water purchased from the city is used for cooling the transformers made the installation of the cooling system profitable.

PRESS OF
J. B. LIPPINCOTT COMPANY
PHILADELPHIA

JOURNAL
OF
THE FRANKLIN INSTITUTE
DEVOTED TO SCIENCE AND THE MECHANIC ARTS

Vol. CLXXX DECEMBER, 1915 No. 6

POSSIBLE SOURCES OF POTASH IN AMERICA.*

BY

FRANK K. CAMERON, Ph.D.,
Member of the Institute.

INTRODUCTION.

The absolute value of the potash market in the United States under normal conditions is relatively small, when compared with that of many other products, being in the neighborhood of $12,000,000. Its importance is very great, nevertheless, for potassium salts are almost a necessity in the production of some of our crops, and are desirable in the production of practically all of them. There are other than agricultural uses where the consumption is much smaller, but where the necessity is even more pronounced, as in the production of certain types of soap and certain kinds of glass. Normally this country obtains about a million dollars' worth of potassium nitrate, nearly all of which comes originally from India, although not always directly. Practically all of this potassium nitrate is used in making fireworks and certain types of powder.

As matters stood before the present European conflict, the consumption of potassium salts for military explosives was insignificant. But it is one of the surprises of the war, even to chemists who are not also experts in military matters, that the

---

* Communicated by the Author.

[Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the Journal.]

Copyright, 1915, by The Franklin Institute.

conflict has brought about such a tremendous demand for types of munitions in which potassium seems to be a necessary constituent, for which there appears to be no satisfactory substitute. Aside from potassium nitrate, as all the world now knows, the whole world's supply of potassium salts came from Germany, from the famous Stassfurt region and from the less well-known Alsatian deposits of rapidly-increasing commercial importance.

The controversies of the year 1909–10 between American importers, the German Kali Syndicate (a selling agency under Imperial supervision), and certain independent producers in Germany led to diplomatic exchanges between the Government of the United States and the German Imperial Government which served at least one good purpose in focussing attention in this country upon the desirability of developing native sources, a desirability confirmed and made more insistent by the unhappy predicament now confronting us. Governmental investigations have been actively in progress since and private initiative has been greatly stimulated. As a result, it has been shown that there are a large number of possible sources of soluble potash salts within the United States, some of which are quite valuable possibly to particular owners, and three and possibly four are potentially possible sources of large commercial importance. At the present writing there is a very small amount of potash salts on hand. The munition manufacturers have been and are still buying eagerly. They prefer the chloride to the sulphate, which is interesting for at least two reasons: it gives a clue to what they are doing with the potash, and it has brought the price of potash, unit for unit, to a higher price in the chloride, though normally the reverse is the case, the sulphate being more highly valued for fertilizers and the chemical industries generally.

No one seems to have any idea, even approximately, as to the aggregate amount of potash salts now in the hands of fertilizer manufacturers and brokers. But it is very clear that the rapidly diminishing imports have about reached the vanishing point, although the world has been scoured for existing stocks, and purchasers for the United States have been as far as Batavia, Borneo. From very recent events it is rather convincingly evident that the embargo on supplies from Germany is not to be lifted until the end of the war. From this point about everything one can say about potash salts is highly speculative. It seems reasonable to expect that prices will be much higher after the war than before, unless workable sources are developed outside of Germany, for potash salts form one of that country's resources that can and probably will be made to shoulder a very large part of the war's expenses. For this reason the ultimate ownership of the Alsatian deposits is of particular interest to the world at large. The Galician and Spanish deposits, as well as those reported from Peru, are possibly of importance, but the information concerning them that is now available offers very slim hopes.

In so far as the technical features are concerned, it has been demonstrated that the United States can produce far more than its own needs in potash salts. Undoubtedly the technology is susceptible of improvement, and of possibly very great improvement. But the potash can be produced, and the real difficulties in the way of a realization of potash production in the United States are purely commercial and not physical.

FELDSPAR.

Of the several possible sources, attention naturally is commanded first by the potassium silicates, such as orthoclase, muscovite, sericite, or lencite, of which large deposits exist in many regions of the country carrying ten per cent. or more of potash (K_2O). There are probably a hundred patented processes for the extraction of potash from such materials, all of which processes fall into two classes. In the first class the spar, or other silicate, is mixed with coal or coke, lime, calcium chloride, sodium chloride, nitre coke, or some combination of these substances, and heated to form a sinter, from which the potash salt is leached. To evaporate the leachings another supply of heat is required, and the final product is never the pure potassium salt, but a mixture with other less desirable substances. To recover all the potassium salt in a pure state by crystallization methods alone is impossible, and to recover it by further chemical manipulations is prohibited by the cost. To meet these objections, the second class of processes has been devised in which the original mix is heated to melting, and thus the potassium is volatilized either as the oxide or as the chloride. Some of the proposed methods have now been tested on a sufficiently large scale to demonstrate their practicability, so far as the physical factors are concerned, and one of them has actually produced a few tons of potassium chloride and oxide.

It is claimed by promoters of these processes that there are known large deposits of spar or other potash silicates which can be worked on the steam-shovel plan and which will yield " run of the mine " material containing ten per cent. or more potash at a low working cost. Usually these costs of producing the raw material have been stated to be in the neighborhood of $1.50 per ton. These claims may, in some cases, be valid, but it is difficult to find a disinterested authority who thinks that there is a deposit from which ten per cent. potash spar can be obtained on a commercial scale without hand cobbing. This would make the cost of production prohibitive, and apparently no disinterested investigator considers it practicable to work a product that approximates ten per cent. or more potash. But, in all fairness to the promoters of potash from feldspar, it should be said that the case is not a proved one, either for or against them, in this regard at least.

Again, every disinterested investigator seems to be convinced that potash from feldspar or other silicate mineral is commercially impossible under normal conditions of the market unless the by-product or residue is salable. So far there seems to be but one practical suggestion: to utilize the residue in making cement. Apparently very good cements can thus be prepared, in some cases cements of very desirable special qualifications. But the cement industry is a large one, worth many times the potash industry. It has grown very rapidly and is now standardized. Practically all cement is now sold under standard specifications, which are not met by the feldspar cements without reference to their intrinsic merits. The cement manufacturers, therefore, are not and can not be expected to be willing to remodel their plants, retrain their operatives, secure, if that be possible, a source of spar, and reëducate the buying public, thus risking the larger and sure business on the chance only of securing a much smaller one.

Certainly one, and, if newspaper reports can be trusted, several cement plants are now actually recovering and marketing flue dust containing a relatively high percentage of water-soluble potash. At the abnormally high prices which the product now commands such flue dust can profitably be collected and prove a godsend to certain consumers of potash salts, as, for instance, the manufacturers of liquid soaps. It is very doubtful if these dusts could maintain a market under normal trade conditions.

DESERT BASINS.

All desert basins, speaking generally, contain considerable stores of water-soluble potassium salts, but usually so mixed with insoluble fill derived from the rim rock as to be quite impossible as commercial sources. A very large number of the desert basins have now been explored more or less thoroughly, and, with one exception, it can now be said that the chance of finding a segregated deposit of potassium salts capable of being exploited commercially is a " miner's chance " only, and a poor one at that. Searle's Lake, in San Bernardino County, California, is, in the ordinary weathers of the desert, a mud flat, but below the surface the solid material is mixed with a brine carrying five or six per cent. potash in the form of the chloride, mainly. But there are large percentages of other soluble substances present—sulphates, carbonates, and borates, as well as chlorides of sodium and magnesium as well as of potassium. It is impossible, by crystallization methods alone, to recover all the potassium from such a brine in anything approximating a pure salt or a mixture of potassium salts only, and the expense of other methods of separation would undoubtedly be prohibitive. It is possible that a segregation of the potassium might be accomplished with a partial elimination of other salts. A large expenditure, reported to be upwards of a million and a quarter dollars, has not yet resulted in a commercial production from this source. One crystallization procedure has been tried out on a large scale and abandoned. It is reported that the present occupants of the site, the Trona Company of California, are trying out another process, the essential features of which are a saturation of the brine with carbon dioxide and the freezing out of carbonates and biborates by reducing the temperature of the mother liquor with an ordinary ice-making outfit. The scheme is an ingenious one, but its practicability in the middle of a large desert seems questionable in the absence of fuller details of this company's plans.

Another difficulty menacing the production of potash salts at Searle's is the validity of the titles of the present possessors.

The Trona Company is controlled by a British corporation, the Consolidated Gold Fields of South Africa, and its holding is the largest ever taken over in the United States by any one individual or company, consequently protestants have arisen, and it is claimed that the original patents on which the title rests were obtained fraudulently. Interested parties claim the possibility that the title of the Trona Company will be rejected and the site withdrawn from entry, pending the passage by Congress of a leasing law. Be this as it may, the uncertainty has hampered, and is hampering, the development of the property. It seems to be the best opinion of disinterested investigators that, ultimately, Searle's Lake may be worked as a source of trona (sodium bicarbonate), with borates and potassium salts as by-products. The production of potassium will be relatively small as compared with the country's needs. Opinions differ as to the probable grade of the potassium salt. The present writer thinks it must be a low-grade one.

ALUNITE.

Near Marysvale, Piute County, Utah, there is a large deposit of massive alunite, an insoluble mineral, with the composition of a basic potassium alumino-sulphate. It is quite similar in composition to alum, hence its name. Other occurrences of alunite in the United States are known, but this is the only one where the material occurs in such form and such quantities as to make it a commercially workable proposition. When roasted, sulphur dioxide and sulphur trioxide are volatilized, and, if the residue be leached, either alum or potassium sulphate is extracted, depending primarily upon the temperature of the roasting. The Roman alum, long a commercial product, is thus obtained from Italian alunite, and it has been reported that deposits in Spain, Italy, Australia, and Japan have at times been small producers.

The technical difficulties in producing potassiums from alunite are not serious. But the deposit is located in a forest reserve. The oxides of sulphur, if allowed to escape into the air, may damage vegetation and bring objection from Federal authorities. If condensed and discharged into the streams they will be a menace to fish life, and thus bring objection from State authorities. Sulphuric acid produced in southern Utah has no obvious market in normal times. Hence what might be an asset in some localities bids fair to be a serious charge on the working of the Utah alunites. The residue, after leaching, is a very fair grade of alumina, and possession of a large source of alumina has long been a fairer vision to the lay chemist than ownership of a gold mine. However, there is but one large purchaser of alumina in the United States, and this purchaser has spent great energy, time, and money in securing to itself the more important deposits of bauxite. Hence it cannot be expected to look with enthusiasm upon the development of another considerable source of alumina. For the Utah operators to undertake themselves to produce aluminum appears to be impracticable, for reasons which need not be discussed here. Other possible uses of the alumina are receiving serious attention, but are as yet of doubtful importance, as a sufficient outlet for the quantity of material for which disposition is desired.

The most serious difficulty affecting the production of potassium sulphate from alunite is the transportation problem incident to the geographical location of the alunite deposit. The sulphate of potassium is the form most favored by agricultural authorities, it is true, and in normal times this is the form of "potash" which should command the readiest and largest market. West of the Mississippi River the citrus region of southern California is the only important market in the United States, and of especial interest because it will not use chlorides, but readily takes a fair amount of the sulphate. Hawaii and Japan are certainly possible markets to be considered. The mountains of Southern Utah are about as unfortunate a location as could well be imagined, since the potassium salt must expect a long rail haul to any important market.

In spite of these difficulties the exploitation of the alunite has been progressing. By far the major part of the material is in the control of two holders. The Mineral Products Company, having close affiliations with one of the largest fertilizer manufacturers in the country, has established a small plant near Marysvale and has recently produced potassium sulphate on a commercial scale. It is too soon, perhaps, to form any definite opinion on the probable success of this venture. The European war has introduced factors which are difficult to evaluate, and, moreover, the entire output of the venture is in the hands of one purchaser, so that the crucial test of the open market is not available.

The Utah Potash Company, a recently-organized corporation for the working of the alunite deposits on the holdings of the Florence Mining and Milling Company, is maturing plans for a large installation near Marysvale, proposing to work under the Morgan patents, roasting the alunite with lime, whereby a lower temperature can be employed profitably and the escape of the objectionable oxides of sulphur is prevented. The plans of this company are predicated on the experience of copper, gold, and other mining ventures where a low-grade ore worked on a large scale is often very profitable when it is a commercial impossibility on a small operation. In fine, potassium salts have been produced from alunite in the United States, and there is a very good promise that they will continue to be produced from this source, even when they come into competition with the German salts following the close of the war.

Among the considerable number of sea algæ on the Pacific Coast of North and South America occur four species which are peculiar to that coast and which have the power of absorbing from the sea-water exceptionally large quantities of potassium. Of these four algæ, or Giant Kelps, as they are known locally, *Macrocystis pyrifera* is undoubtedly the most important. It reaches its best development south of Point Sur, on the California coast, and north of the Cedros Islands, off the coast of Mexico, where it occurs in large beds or groves from a few acres in extent to fifteen square miles or more. The entire kelp beds along the coast of the United States and Alaska aggregate 400 square miles or more, and could be made to yield annually, under careful harvesting, some six or seven times the normal demands of the United States. The California beds alone could easily produce more than our present normal requirements.

The *Macrocystis* plant, when freshly harvested, contains from three to five per cent. potassium chloride. The oven-dried plant will average probably sixteen per cent. potash (K_2O) in the form of chloride. The dried plant also contains something less than two per cent. nitrogen, and, being fibreless, it goes to pieces in the soil quickly and readily. Pot and garden experiments with dried kelp have shown it to be an excellent fertilizer as compared with equivalent amounts of the ordinary soluble potassium salt.

Harvesting of kelp on a scale comparable with commercial conditions has now been done by a sufficient number of different investigators to have definitely demonstrated the practicability and low cost of the operation. The cost of drying artificially the harvested product has not been worked out so satisfactorily, but enough has been done to show that it is very probably feasible as a commercial operation when the technology of the operation has been adapted to the peculiar characteristics of the material adaptations which will speedily come with more practice and actual contact with the material. Apparently a modern rotary drier is the type most promising, since the wet kelp, when heated in a furnace where a stirring is not provided, quickly mats down to a sticky mass, from the surface of which potassium chloride may be volatilizing, while at the same time the wet interior is at a temperature quite durable to the hand.

While dried kelp is itself a good fertilizer and seems admirably adapted to use in mixed fertilizers, and can probably be produced at a cost which would insure a good profit on the basis of before-the-war prices, it is possible that kelp ash may be more worthy of consideration for the Eastern market. In this material, naturally, there is no nitrogen, but there is about sixty per cent. potassium chloride, the remainder being mainly sodium chloride. But it is as a source of pure potassium chloride that kelp has the most promising future. The kelp ash contains, when not too severely burnt, very little soluble material other than potassium and sodium chlorides. Theoretical deductions backed by laboratory experiments have shown the feasibility of a separation of true salts by treating a fixed mass of water with easily calculated amounts of the particular ash, at alternate temperatures, whereby there is a practically complete recovery of the potassium chloride in a nearly pure condition. The writer's own observations and studies have convinced him that these giant kelps offer by far the cheapest and most feasible source known for the production of a practically pure potassium chloride in very large quantities.

But while the future of the potassium sulphate from alunite appears with almost a certainty to lie in fertilizers and in a minor degree as a raw material for the production of potassium carbonate, a pure potassium chloride from kelp would probably find quite different openings. Undoubtedly some of it would be utilized in fertilizers, but mainly it would be used in the production of potassium chlorate. Potassium chlorate is the basis for a type of "permissive" explosive much favored by construction engineers in the West and growing in favor everywhere. It is probable that a big impetus will be given to its use by the favor which it has found in the present war, but it is particularly as a necessary raw material in the production of safety matches that it is desired. This country could, and probably would, soon become the largest producer of safety matches with a satisfactory development of the kelp industry.

It seems desirable here to point out that, while there may be useful by-products from kelp developed some time in the future, there is no great promise of such in sight at the present time. The oft-heralded promise of cheap iodine is purely illusory. The main, practically the only, commercial source of iodine in the world to-day is the mother liquor from the crystallization of Chili saltpetre. But only about one-twelfth of the possible yield of iodine from this source is recovered in peace times, simply because the world's demands are thus fully satisfied, and the cost at which iodine can be produced in Chili would make it impracticable to recover it from the kelp, though there are no serious technical difficulties in so doing.

The *Macrocystis* has a life-history longer than one calendar year. It is probably a perennial. Moreover, harvesting it to a moderate depth appears to produce a stooling effect, causing it to grow more thickly and heavily. As the average length of a full-grown plant is about 100 feet, from 30 to 70 feet of the plant's length is streaming along near the surface with the tide or wind, and a cutting of four to six feet leaves no noticeable effect upon the harvested area. Consequently it seems probable that several cuttings a year can be made without damage to the bed. Indeed, observations on harvested areas indicate a decided improvement in growth is likely to ensue.

The beds all lie within the one marine league limit, hence control of them is vested in the State and not in the Federal Government. There appear to be no State laws applicable. Capital is notoriously timid of competition, and competition, even to the harvesting of the same bed by rival interests, is quite possible now, legally as well as physically. Moreover, however unfounded the fear may be, there has been a very real fear on the part of capital, in the absence of any pertinent laws, that it might become the victim of unfriendly legislation, and there has been a very real fear of the possibility of trouble from unscrupulous individual legislators. It has been the lack of adequate State legislation that has been, and is yet, the principal bar to the development of a potash-from-kelp industry.

Small amounts of dried kelp, kelp ash, and high-grade potassium chloride have been produced. One operator produced in all something over twenty tons of potassium chloride, but the company was improperly financed, was the victim of improper promoting and wildcat stock-jobbing, and was forced, because of its financial difficulties, to come to a stop just when it had demonstrated its ability to produce a high-grade product at a cost insuring a profit.

SUMMARY.

From the foregoing it appears that there are within the United States large stores of raw materials from which it is possible to obtain ample supplies of potash salts; that the technology of the subject is sufficiently developed to demonstrate the entire practicability of a supply from native sources, so far as physical factors are concerned. We can have "potash" if we really want it and are willing to pay for it. There are, however, serious commercial doubts affecting each of the four possible sources, and concerning the validity of these doubts opinions may well differ. Those most familiar with the problem are the most sanguine of the probability of commercial success.

While it is undoubtedly true that governmental efforts can yet furnish assistance, there is a very serious doubt as to how far these efforts should be continued. The time seems to have arrived when the commercial interests should themselves squarely assume the tasks confronting them and the costs of what further experimenting is necessary. This they have been slow to do, but there is rapidly accumulating evidence that these interests are responding to the spur of necessity, and that sooner or later potash salts from American sources are to be upon the market. An early cessation of the European war might delay but can no longer stop the development of our potash resources.

The Value of Standards in the Manufacture of Automobiles. K. W. ZIMMERSCHIED. (*Midwest Section Society of Automobile Engineers*, October, 1915.)—The most potent factor in the brilliant rise of the mechanical industry of America is the almost universal adoption of the principles of interchangeable manufacture. There are underlying reasons for the opportunities that have arisen continually before us, but no nation with so few skilled mechanics as ours could have ever taken advantage of these opportunities so adequately without possessing the genius to conceive the idea of assembling things from parts wholly produced by automatic machinery. But even such genius could not have brought success had the final conception failed to include the provision that all such automatically-produced parts should be so alike as to be interchangeable. The whole scheme of interchangeable manufacture is based upon the use, conscious or not, of standards of measure, of form, of material quality, of workmanship.

In the automobile industry it was found that many of the older established standards were inadequate for the conditions encountered in the building and maintenance of high-duty road mechanisms and have been modified or amplified to meet these conditions. In addition to standards of form, the new varieties of steel as well as non-ferrous alloys have been standardized, and precise specifications eliminate the mystery surrounding various alloy steels sold at high prices under various trade names.

Establishing practical standards is one of the most valuable activities of the Society of Automobile Engineers. Those standards established by it have proved adequate to meet a great variety of conditions, and nearly all of them have been accepted widely by the trade.

American-Made Tracing Cloth. ANON. (*Engineering Magazine*, vol. l, No. 2, November, 1915.)—To the National Tracing Cloth Company is due whatever credit there might have been in placing American-made tracing cloth upon the market. For years American consumers were dependent on imported cloth, good, bad, and indifferent. Since the inception of the National Tracing Cloth Company, about five years ago, it is possible to get a cloth of American make of superlative grade and at a price considerably lower than that of the best imported brands, to which it is in no degree inferior.

National tracing cloth is made at Saylesville, R. I., the manufacturing plant being part of the Sayles' Bleacheries. The company started rightly by using a basic cloth of exceptional excellence as a foundation of its finished article, made from selected yarn of long staple, giving it a stability of character both in material and finish, so desirable when a drafting department desires to file away its drawings for reference in after-years.

THE CRACKING AND DISTILLATION OF PETROLEUM UNDER PRESSURE.*

BY

BENJAMIN T. BROOKS, Ph.D.,

Mellon Institute of Industrial Research, University of Pittsburgh.

THE great increase in the consumption of gasoline during the last decade induced the apprehension that a serious shortage of petrol, or gasoline, suitable for use in motor vehicles would result. This has recently resulted in a small flood of patents describing various processes which have for their object the conversion of the heavier and generally less valuable petroleum oils into gasoline. The public press does not even yet seem to be aware of the steady development which has been going on in the petroleum industry and which now enables us to say with certainty that no serious shortage of gasoline will ever inconvenience the automobile trade so long as petroleum of even the heavier grade is produced in anything like the quantity now being brought forth in the world's various petroleum-producing centres. Several independent groups of investigators have contributed to the solution of this problem, and, although this cannot be considered a closed chapter of industrial research, certainly more than the preface has been written, since more than one method has been shown to be capable of successful, commercial, large-scale operation.

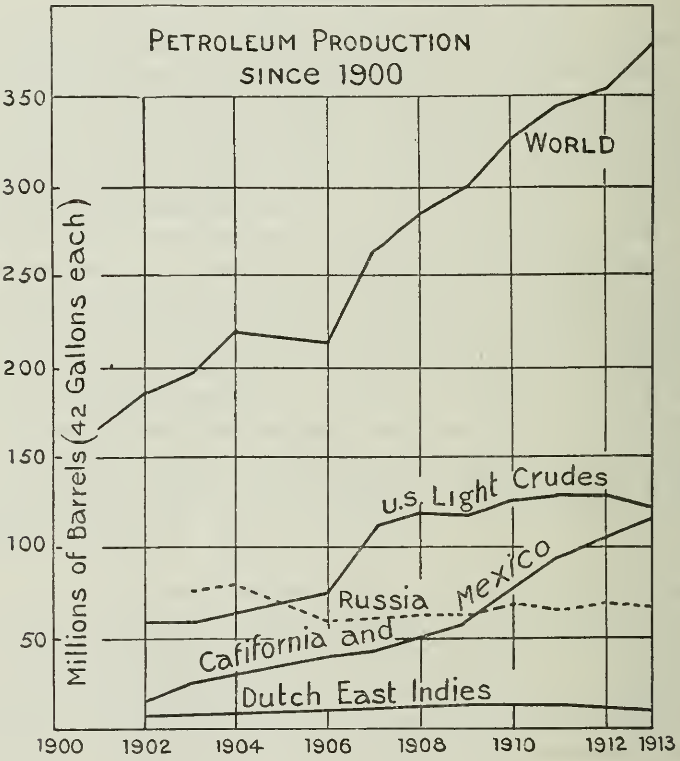
The great economic importance of the problem is indicated by the following facts, here briefly presented in abstract form. A good index of available natural or primary gasoline is obtained by reference to the crudes which yield it. The world's production of petroleum since 1900 is graphically shown in Fig. 1. Attention should be called to the fact that the greatest increases in the production of crude have been in fields yielding heavy oil containing little or no gasoline, as is the case with Californian and Mexican oils.

In 1910 there were in the United States, as nearly as can be ascertained from the registration statistics, about 350,000 motor vehicles in use; in 1911 the figure given was 550,000; in 1912 this total had mounted to 990,700, and, by the end of 1914, 1,808,000 motor vehicles had been registered.[1] More accurate data are available, giving the number of automobiles manufactured in this country since 1903. This is shown graphically in Fig. 2.

---

* Presented at the meeting of the Section of Physics and Chemistry held Thursday, October 7, 1915.

FIG. 1.



World's production of petroleum since 1900.

The economic aspects of the motor fuel question are more fully discussed by the author in a recent number of the *Journal of Industrial and Engineering Chemistry*.[2] The following represent the principal factors in the question of an increased supply of motor fuel and show that cracking methods for the manufacture of gasoline must become of increasing importance:

---

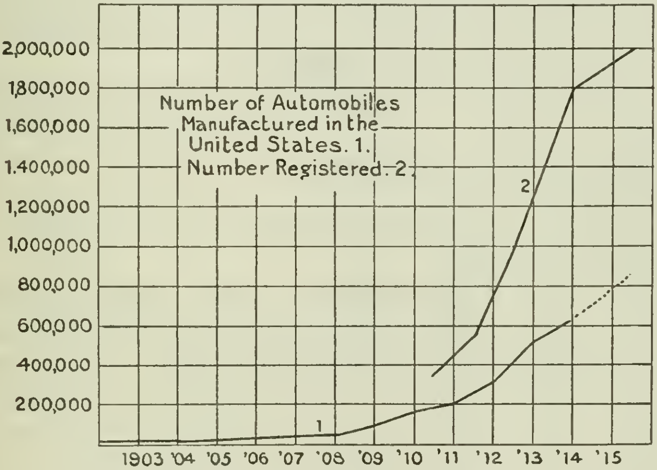
[1] *Oil Paint and Drug Reporter*, March 15, 1915. *The Automobile* for August, 1915, states that the registration statistics show that 2,070,900 cars are now in use in the United States.

[2] *J. Ind. and Eng. Chem.*, 1915, 7, 177.

1. The supply of motor fuel can be nearly doubled by employing spirit of about 56° Be. gravity and constituting the entire distillate boiling below 200° C. from high-grade crudes yielding gasoline.

2. Natural-gas gasoline, made by cold compression of "wet" natural gas, may yield, in the United States, 500,000 to 600,000 barrels. If this is blended with heavy naphtha so as to produce a heavier mixture suitable for use in automobiles, the total increase available will be approximately 1,000,000 barrels, or less than 4 per cent. of the production of "primary" gasoline distilled from crudes in the United States.

FIG. 2.



Automobile statistics for the United States.

3. The shale oil industry is of no importance in this country, and in England is practically in a static condition, and increased amounts of motor fuel can hardly be looked for from this source.

4. If all the by-product coke ovens now operating, or nearing completion, in the United States were equipped with benzol recovery plants, the total production of benzol would be approximately 30,000,000 gallons (recovering 2 gallons of benzol per

ton of coal). By the end of the present year about 7600 by-product ovens will be in operation in this country.[3]

5. The price of 95 per cent. alcohol for industrial purposes is normally 30 to 35 cents per gallon. This alcohol has only about 60 per cent. of the calorific power of gasoline and has not been employed for motor fuel in England in normal times, when gasoline sold for 40 to 42 cents per gallon.

The earlier attempts to convert heavy petroleum hydrocarbons of high boiling-points into lighter, more volatile products were carried out with the object of increasing the yield of illuminating oil. But in very recent years the cracking problem has been attacked anew and with the object of increasing the yield of gasoline, or motor fuel. The methods which have been employed to attain this end may be considered to be modifications of the following three general methods:

1. Heating heavy oil to cracking temperatures at atmospheric pressure.
2. Heating heavy petroleum oils to cracking temperatures under pressure.
3. Chemical decomposition effected by chemical reagents, such as aluminum chloride.

In discussing the first method, it should hardly be necessary to point out that the temperatures prevailing in the old cracking process for kerosene are not sufficiently high to produce greatly increased yields of gasoline. On the other hand, very high temperatures (*e.g.*, 900° C.) have been employed in the cracking of petroleum, as for the manufacture of Pintsch gas. In the latter process, about one gallon of light volatile liquid is obtained by compressing 1000 cubic feet of the gas.[4] A sample of this product, Sp. gr. 0.830, recently examined in this laboratory, yielded 88 per cent. distilling below 115° C. It was a very highly unsaturated product, and when carefully treated with cold concentrated sulphuric acid this sample lost 48.0 per cent. to the acid. The principal constituent of the remainder was benzol.

---

[3] Püning (*Iron Trade Review*, 1913, 625, 653) gives 6200 by-product ovens in the United States at the end of the year 1913.

If the number of by-product ovens becomes sufficient to supply the 40,000,000 tons of coke now consumed by our blast furnaces when they are working full capacity, we can reckon on a possible annual production of benzol of about 80,000,000 gallons.

[4] Armstrong, *J. Soc. Chem. Ind.*, 1884, 464.

Experiments carried out in this laboratory show that at temperatures within the range 430° C. to 600° C., Solar oil, Sp. gr. 0.8862, yielded from 3 to 20 per cent. of the gasoline boiling below 150° C. The gasoline so produced was highly unsaturated, the loss on treating with one-fifth volume of concentrated sulphuric acid averaging about 28 per cent. The presence of contact substances appeared to be without effect, except in the case of nickel, when the amount of gas produced was greater and the gasoline fraction of the resulting product showed a much greater loss to the sulphuric acid than when other contact substances were employed. A few of the experiments of this series are noted in the following table:

TABLE I.

Results of the Crackinig of Texas Solar Oil at Atmospheric Pressure.

No.	Contact substance	Per cent. boiling below 150°	Temperature C. Centigrade	Time in hours	Per cent. loss gas and coke
1.	None	8.3	500°	0.5	8.7
2.	Pumice	8.8	420°	2.0	12.8
3.	Pumice	15.6	500°	2.0	17.5
4.	Nickel wire	12.3	500°	2.5	16.1
5.	Nickel wire	18.8	500°	5.0	16.5
6.	Nickel on Al_2O_3 + H	10.5	500°	2.5	15.1
7.	Nickel on Al_2O_3 + H	17.9	600°	2.0	30.8
8.	Copper on charcoal	14.7	500°	2.0	13.1
9.	Copper on charcoal	9.4	450°	6.0	12.0
10.	Copper gauze	14.1	500°	2.0	11.4
11.	Copper gauze	15.2	500°	2.5	11.8
12.	Copper gauze	18.8	500°	4.5	17.1
13.	Copper gauze + H_2O	15.5	600°	2.0	11.1
14.	Iron	4.5	400°	2.7	...
15.	Iron + H_2O	8.6	450°	2.0	...
16.	Iron + H_2O	8.5	480°	3.5	...

If the cracking of a paraffin hydrocarbon is expressed by the equation—$RCH_2 - CH_2CH_2R_1 \longrightarrow RCH_3 + CH_2 = CH.R_1$—one might expect that the per cent. by volume of unsaturated hydrocarbons would approximate 50 per cent. of the product. However, separation of carbon and gaseous products, polymerization of the olefines, and formation of naphthenes occurs.[5] I have found formaldehyde and formic acid among the products of the autoxidation of cracked oils, which fact may be considered as an indication of the presence of the methene group ($=CH_2$).[6]

It is, of course, obvious that, if hydrogenation could be carried out successfully in a commercial way, the customary treatment with sulphuric acid could be dispensed with. However, we have found that the ordinary desulphurization methods, even when most carefully carried out, apparently left traces of sulphur in the oil, so that, after comparatively very little use, the catalysts, both nickel and palladium, were rendered inactive.

In view of the recently-proposed method of Bergius, of hydrogenating without a metallic catalyst, an experiment was made in which a sample of cracked gasoline, iodine number 55.0, was maintained at 196° C. for 30 hours under a hydrogen pressure of 3000 pounds per square inch. The iodine number of the gasoline, after the experiment, was 52.9, an effect probably accounted for by polymerization, since a similar reduction in iodine number was brought about in an atmosphere of nitrogen.

Since petroleum technologists have come to associate the characteristic, strong and unpleasant odor of cracked oils with olefines, and sometimes attribute the objectionable odor to their presence, it is worth while to note that highly-cracked gasoline, which had been treated with alkaline plumbite, or thoroughly desulphurized by copper oxide, had lost nearly all of its offensive, so-called odor of cracked oils. Metallic sodium is even more effective in producing sweet-smelling gasoline, although the percentage of olefines remains unchanged. Pure olefines have a sweetish, agreeable odor. The odor of pure olefines or of cracked gasolines, which have been purified as by metallic sodium, while agreeable, is not exactly like the customary odor of gasoline, and, it might be said, neither is exceedingly pure normal heptane. Much to my surprise, I found that the cracked oils, desulphurized and otherwise purified by metallic sodium, held their water-white color and were very decidedly better, even in respect to odor, than good commercial "primary" gasoline, after the two samples had been exposed side by side to light and air for six months. The same marked difference was noted in the case of a sample of "primary" gasoline from Oklahoma crude, part of which was treated with metallic sodium and the second part "refined" by sulphuric acid in the usual manner. Sulphur compounds, perhaps in the sulphite condition, appear to catalyze the autoxidation of such refined oils, although Willstätter[7] has shown that sulphur, in the form of the element at ordinary temperatures, does not accelerate oxidation. The offensive odor of cracked petroleum oils is due to small quantities of sulphur compounds, naphthenic acids, and basic nitrogen compounds, the latter probably of the pyridene type. Pure olefines slowly assume a pungent, disagreeable odor by autoxidation, peroxides, formaldehyde, formic acid and traces of other fatty acids, carbon dioxide, and resinous products being formed.

---

[5] Engler and Gruning, *Ber.*, 33, 1900, 2915. Engler and Lehmann, *Ber.*, 30, 1897, 2367. Krämer and Spilker, *Ber.*, 33, 1900, 2268. Nastjukoff, *J. Russ. Phys. chem. Ges.*, 1904, 881.

[6] Cf. Wallach, *Ann.*, 343, 1905, 34.

A number of processes have been patented which propose to hydrogenate the unsaturated hydrocarbons as they are formed, as by placing platinum or palladium in the cracking still. Others pass the oil vapors with steam through heated pipes, the claim being made that the steam and oil, or steam and carbon, react to give carbon monoxide and hydrogen, a claim which can undoubtedly be substantiated, if sufficiently high temperatures are employed. Another method, which is said to have been tried on a large scale, is that of passing the steam and oil vapors together over scrap iron at 540° to 650° C. Other processes propose cracking in the presence of nickel with or without steam. Another patentee employs oil and steam vapors over "red-hot" alumina, and another introduces coke into the oil-steam combination, an addition which those familiar with the cracking problem doubtless deem an unnecessary expedient. Our results with the steam-iron method indicate that hydrogenation of olefines under these conditions is not appreciable, and W. A. Hall[8] has recently recorded experiences with the oil-steam-iron process which confirm our own. Hall states that he found steam totally inadequate as a means for preventing carbon deposits, and that "the extent of the hydrogenation was hard to determine, but, at all events, the spirit produced was so largely unsaturated that hydrogenation could not have been of much consequence, and, although we do not know what became of the small amount of hydrogen evolved, we do know that the oxygen was sufficient to destroy completely the tubes in a surprisingly short space of time."

---

[7] *Ber.*, 1914, 2801.

[8] *Engineering*, 1915, 250; *J. Gas Lighting*, 1915, 455.

Another group of patents describes heating heavy oil under pressure, subsequently distilling at atmospheric pressure. The early experiments of Thorpe and Young,[9] who heated paraffin under "a high pressure," obtaining a light oil which contained pentane, hexane, octane, and nonane, and the work of Ipatiew[10] on the polymerization of ethylene, probably the most stable olefine hydrocarbon, and the work of Engler,[11] who showed that typical petroleum olefines could be converted into saturated naphthenes, induced us to follow up this line of work. Engler and Halmai[12] heated a heavy cylinder oil to 430° to 470° C. under 120 atmospheres pressure and by three successive treatments obtained 52 per cent. boiling below 180° C., specific gravity 0.755. This method has also been described recently by Snelling,[13] who employs 800 pounds pressure. In order to compare the results obtainable by heating under pressure and subsequently distilling at atmospheric pressure, we heated Oklahoma reduced oil, containing no constituents boiling below 275° C., for two hours under a pressure of 180 pounds per square inch, the pressure being that developed by its own vapors and decomposition products. We obtained 5 per cent. gasoline by subsequently distilling at atmospheric pressure. In another experiment in the same apparatus, with the same quantity of reduced oil and also of two hours' duration and 180 pounds pressure, we obtained 30 per cent. of gasoline by distilling the gasoline as fast as formed.

Little light, if any, can be thrown on this matter by attempting a mathematical discussion of the equilibria in such so-called systems. Suffice it to be said that according to familiar principles of equilibria, which we may qualitatively apply for the purpose of explanation, this difference, noted above, is evidently due to the fact that the gasoline hydrocarbons themselves are decomposed and, to obtain maximum yields, should be removed from the source of heat or sphere of reaction. Also, if the lighter, more volatile products are removed as fast as formed, the heavy residual matter in the still becomes continually hotter. This is shown by the following temperature curve obtained during distillation of Oklahoma reduced oil under 100 pounds pressure, the temperature being recorded by a thermo-couple in the oil several inches from the still bottom (see Fig. 3).

---

[9] *Chem. News*, 1871, **23**, 124; 1872, **26**, 35.

[10] *Ber. d. deut. chem. Ges.*, 1911, **44**, 2978.

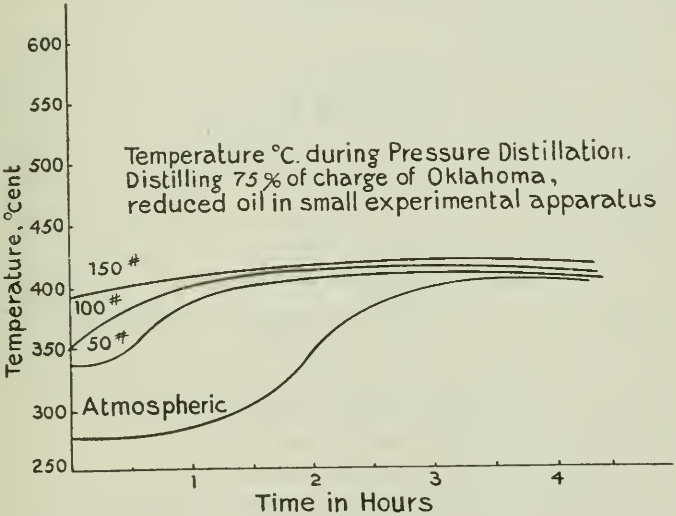
[11] *Ibid.*, 1900, **33**, 2915; 1909, **42**, 4610, 4613, 4620; 1910, **43**, 388.

[12] *Ibid.*, 1910, **43**, 397.

[13] *Bull. Am. Inst. Mining Engineers*, 1915, 695.

Operating by the Snelling method, the temperature within the still becomes lower and lower, if constant pressure is maintained, due to the accumulation of gases and volatile products in the still. This must have the result that the more stable hydrocarbons are not cracked. The emphasis Snelling places on the ratio of the volume of the charge to the total volume of the still obviously is to be interpreted that, if one were to fill the still nearly full, one could easily attain excessive and dangerous pressures, such as the 800 pounds mentioned by Snelling, before temperatures sufficiently high to crack the oil would be reached. If the still is charged with only a relatively very small quantity of oil, say one-twentieth volume, the whole of it might easily be converted into gas and coke without producing the said pressure.

FIG. 3.



A modified form of the process of heating oil under pressure and subsequently distilling at atmospheric pressure has been patented by Testelin and Renard,[14] who describe heating oil in pipes to temperatures not exceeding 450° C. and maintaining "sufficient pressure on the oil to keep it in the liquid state." Clark [15] varies this by pumping the oil through heated pipes and passing the hot oil into a receiving drum, where distillation of the lighter products can take place. One object of the Clark method appears to be to minimize the deposition of coke in the heated pipes by the rapid passage of the oil through them. The Clark patent seems to be practically the old method of Benton, except that Benton permitted the lighter products to distil by *release* of the pressure.

In the course of our work on the distillation of heavy petroleum oils, in most cases Oklahoma reduced oil 30° Be., we have operated up to working pressures of 450 pounds per square inch. Young [16] employed 10 to 20 pounds per square inch. Dewar and Redwood [17] described distillation of heavy oils under pressure, but failed to state what pressure and did not indicate that the conditions of their method favored the production of gasoline. Boleg [18] recommended four to six atmospheres for "illuminating oil," and Krey [19] described the results of distilling oil under pressures of three to six atmospheres, the results of which are also described in considerable detail by Engler.[20] Laing [21] also recommended the employment of 80 pounds pressure for carrying out cracking distillation of heavy petroleum.

On operating under pressures higher than those mentioned, we obtained continually increasing yields of gasoline up to about 250 pounds per square inch, when the yield diminished with further increase of pressure, the relative amount of coke and gas formed rapidly increasing beyond this point. The marked influence of pressure upon the percentage of olefines in the gasoline produced is also shown graphically in Fig. 4.

---

[14] English Patent 3413, February 10, 1913.

[15] U. S. Patent 1,119,496, December 1, 1914.

[16] English Patent 3345, December 27, 1865.

[17] U. S. Patent 419,931, 1890; 426, 173, 1891.

[18] *Chem. Rev.*, 9, 1898, 24.

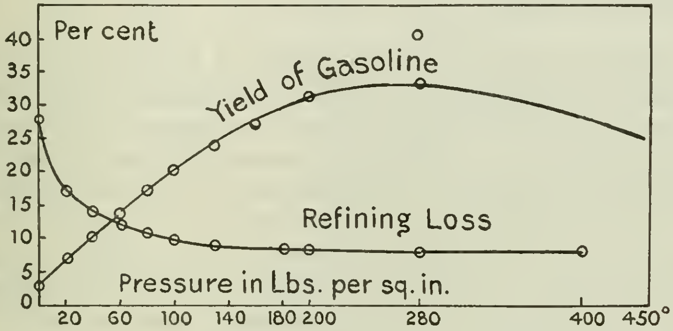
[19] German Patent 37,728, 1886.

[20] *Ber. d. deut. chem. Ges.* 30, 1897, 2919.

[21] English Patent 11,757, 1890; 260,858, 1911.

This *decrease in the percentage of olefines* in the resulting gasoline is undoubtedly due to their polymerization, not to hydrogenation, although Ipatiew observed that, in the distillation of petroleum under pressure, the evolved gases become continually poorer in hydrogen as the pressure is increased, in spite of the higher temperatures required to maintain the higher pressures. At a given temperature it is obvious that increase of pressure would tend to prevent dissociation with the formation of gaseous products. Engler[22] obtained no hydrogen from kerosene by heating to temperatures below *470° C.* Uebbelohde and Woronin[23] showed that, in the presence of nickel, hydrogen was dissociated from a Baku crude oil at as low a temperature as 180° C. In view of the results, quoted in Table I, I did not consider that cracking petroleum in the presence of nickel, even under pressure, was likely to give a satisfactory product. Sabatier and Mailhe[24] propose to make highly unsaturated gasoline by cracking in the presence of red-hot nickel and subsequently hydrogenate the resulting product. Hall[25] cracks oil in the form of *vapor* at 600° to 650° C. in the presence of nickel and under 50 to 75 pounds pressure, and obtains a highly unsaturated product, but very rich in benzol and its homologues. The effect noted by Ipatiew is evidently that of pressure on the character of the

FIG. 4.



Yield of gasoline by distilling Oklahoma reduced oil under pressure and refining loss of gasoline so produced on treating with sulphuric acid.

---

[22] "Das Erdol," I, 574.

[23] *Petroleum,* 1911, 7, 9.

[24] U. S. Patent 1,124,333.

[25] English Patent 17,121, 1913.

dissociation of the hydrocarbons. We have analyzed the gases evolved during distillation of Oklahoma reduced oil at 110 pounds pressure and find that the percentage of hydrogen in the evolved gases is extremely small.

TABLE II.

Gases from Cracking Distillations Under 100 *Pounds Pressure.*

	(a) From Jennings crude.			(b) Paraffin.		
Sample No.	I	II	III	I	II	III
Temperature in still	340°C.	415°C.	422°C.	417°C.	432°C.	437°C.
CO_2	1.2	0.5	0.0	0.0	0.0	0.0
CO	1.2	0.5	1.3	0.0	0.0	0.0
Illuminants	15.4	15.3	13.0	25.4	37.0	33.5
Hydrogen	0.0	4.0	4.4	0.3	0.9	3.0
Saturated hydrocarbons	81.5	79.7	81.3	74.3	62.1	63.5

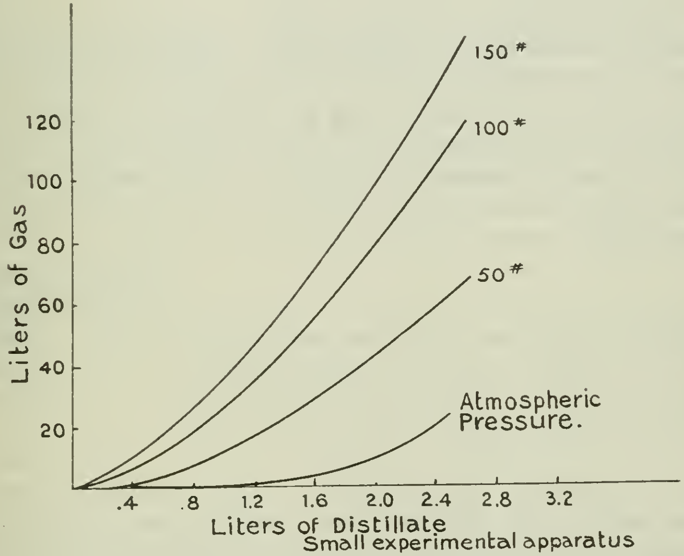
Another noteworthy fact brought out by the above table is that higher temperatures are required to "crack" paraffin than a mixture of the cyclic hydrocarbons or naphthenes as represented by the Jennings oil. Paraffin is also more stable toward aluminum chloride than naphthenes of about the same range of boiling-point.

The increased yields obtained above 100 pounds and the smaller percentage of olefines in the product constitute the basis of United States patent No. 1,101,482. The results quoted in Fig. 4 were obtained in a small laboratory apparatus and do not represent the maximum yields obtainable, nor the highest quality of product. The ratio of heating surface to the volume of oil in the still affects markedly the rate at which cracking distillation can be carried out. Were the process merely one of distillation, this would seem too obvious to mention. However, the *cracking* of the oil apparently occurs chiefly at the heated surfaces, where the heat is supplied to the oil, and considerable time must be allowed for the oil to be cracked to the lighter hydrocarbons and *too rapid distillation prevented,* as by slow firing and refluxing the heavier fractions back into the still. *Slow* and less intense firing of the still also has the result of greatly diminishing the percentage of olefines in the gasoline produced, although the yield of gasoline is much increased.

We have found that the amount of gas evolved and coke deposited increases very rapidly as the working pressure is increased beyond 100 pounds. This figure varies considerably in different apparatus and with different distillation rates. Small laboratory apparatus gives more coke and gas and more highly unsaturated gasoline than large apparatus. The rate at which gas is given off during distillation of a given charge of oil at constant pressure is greatest during the coking stage, *i.e.,* after 85 per cent. of the charge has been distilled—a procedure naturally not carried out in practice. This is shown by the curves in Fig. 5.

The *percentage of coke deposited* also varies greatly according to the form of the apparatus and the method of operating. Thus very little coke is deposited in an ordinary horizontal still during

FIG. 5.



Gas evolved on distilling three litres Oklahoma reduced oil in small experimental apparatus.

distillation at 100 pounds, if not more than 60 per cent. of the charge is distilled. This will naturally vary greatly with the character of the oil charged into the still. With clean paraffin distillate in a still of the Burton type, the amount of coke deposited in 24 hours from 200 barrels charge rarely exceeds 125 pounds. We have found that, if the heating surfaces are vertical, the quantity of coke deposited is not more than one-fifth as much as is obtained under the same conditions but with the heating surfaces horizontal, as on an ordinary still bottom. If the distillation is not carried out beyond 60 per cent. of the charge, a large part of the coke remains suspended in the residual oil as gritty, sandlike particles.

We have made use of the above-mentioned facts by so operating [26] that the heating surfaces are vertical, maintaining a large ratio between heating surface and volume of oil charged and removing the sandlike coke particles, by gravity and flow of oil through the apparatus, into a cooler zone, which prevents their cementing together in the form of a hard, compact mass. Another patentee [27] places false bottoms in horizontal cylindrical stills, which collect much of the coke that would otherwise deposit on the hot bottom.

We are unable to confirm the claims made by Burton to the effect that condensing the vapors under 75 pounds pressure yields gasoline of saturated character, whereas releasing the vapors close to the still and condensing them at atmospheric pressure yields gasoline of too unsaturated character for industrial use. By distilling Oklahoma reduced oil under 80 pounds pressure, we obtained by both methods products which were practically identical in this respect.

	Vapors condensed under	
Gasoline:	80 pounds pressure	Atmospheric pressure
Per cent. refining loss to 5 per cent. concentrated H_2SO_4 ..	7.9	8.0
Per cent. refining loss to 5 per cent. fuming H_2SO_4	12.2	12.0
Kerosene:		
Per cent. refining loss to 5 per cent. fuming H_2SO_4	9.0	8.0

The very slight change resulting from heating a cracked oil, iodine number 55.0, for 30 hours at 196° C. under a hydrogen pressure of 3000 pounds per square inch, certainly indicates that polymerization of petroleum olefines does not occur to an appreciable extent below 200° C. The experiments of Semmler [28] on the polymerization of isoprene, myrcene, and other hydrocarbons by heating under pressure are interesting in this connection. The polymerization of butadiene derivatives by heat and pressure occurs much more readily than is the case with other olefines, at least so far as known. By heating myrcene four hours at 250° to 260° C., Semmler obtained a 50 per cent. yield of the diterpene

---

[26] U. S. Patent 1,131,309.

[27] Humphrey, U. S. Patent 1,122,000; 1,122,003. 1914

[28] *Ber. d. deut. chem. Ges.*, 1913, 1569.

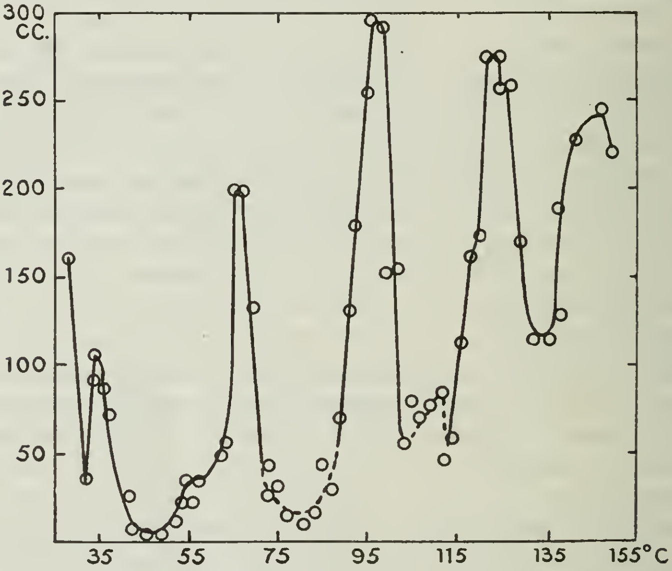
$C_{20}H_{32}(F_3)$. It should be noted that the product is still highly unsaturated, containing three double bonds. It is my opinion that during the distillation of petroleum oils under pressure polymerization of the olefines formed occurs in the still proper, where higher temperatures, 380° to 420° C., prevail, not, as claimed by Burton, in the water-cooled, condenser coils, where much lower temperatures are the rule. We are now engaged in studying this question of polymerization of olefines by heat and pressure at regular temperature intervals above 200° C.

However, the successful manufacture of gasoline on a large scale by cracking heavy oil under pressure was first carried out by Burton and his associates at the Whiting refinery of the Standard Oil Company. Although the arrangement of Burton's apparatus is essentially the same as that of Dewar and Redwood, and the pressure employed by him, 75 pounds per square inch, was employed previously by others, Burton demonstrated that such distillation could be *safely* carried out on a large scale.

Several years ago we carried out experiments on the cracking of oil in the form of vapor under various pressures. After working with a semi-large unit, a still 20 feet long and 30 inches in diameter, under pressures up to 275 pounds per square inch, we believed that the danger from explosion could be considerably lessened, if the oil could be passed continuously in the form of spray or vapor through a suitable apparatus, so that the amount of liquid oil under heat and pressure at any moment would be relatively small. In view of the fact that this process has now become rather well known, I shall not go into detail further than to state that, except when the temperature was very carefully controlled, the deposition of coke was greater than when the apparatus contained liquid oil under the same pressure. Regulation of the pressure by permitting the gaseous products to accumulate or by introducing gas, such as hydrogen or water gas, is also a factor. Heavy oil cannot be completely vaporized at any except very low pressures. With the heavier oils, cracking begins at once when vaporization is attempted. Tar or coke particles coming into contact with the heated walls of the apparatus become cemented there, whereas when filled with oil the rather violent motion of the oil in ebullition tends to entangle and carry away the coke particles, and the heavy residue, carrying as much as 15 per cent. of sandlike coke, depending upon the conditions of operation, is slowly swept out of the apparatus when operating on the continuous system as we have done, or is caught on the false bottoms provided for the purpose in the Burton-Humphries method.

We have examined the gasoline made from Oklahoma reduced oil, 30° Be., by distilling under 100 pounds pressure and find that, in addition to approximately 8 per cent. of benzol, toluol, and metaxylol, the gasoline appears to consist chiefly of normal paraffin hydrocarbons.[29]

FIG. 6.



Fractional distillation curve for gasoline made by distilling Oklahoma reduced oil under 100 pounds pressure.

The public press has recently given a great deal of space to the possibility of manufacturing benzol and toluol by cracking petroleum vapors, at temperatures within the range 600° to 650° C. and under 75 pounds pressure. A communication to the author from W. A. Hall states that a large plant, erected at Thames Haven, England, has been taken over by the government for the manufacture of benzol and toluol, employing as a raw material the ordinary fuel oil used in the British Navy. Mr. Hall says: "I can state that the spirit derived from this cracking operation contained 22 per cent. of C. P. toluol, as determined by Sir Boverton Redwood, who has had the whole matter in charge."

---

[29] Experimental work done by I. W. Humphrey.

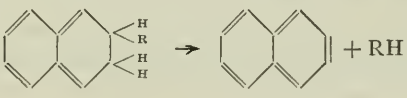
The formation of aromatic hydrocarbons from petroleum oils has heretofore been assumed to be due to complex and little-understood changes, such as dehydrogenation of naphthenes and the formation of acetylene, and the condensation of the latter to benzene and its homologues.

We have found the above-named aromatic hydrocarbons in gasoline made by cracking heavy Oklahoma reduced oil under a pressure of 100 pounds per square inch. Treatment of the gasoline so obtained by liquid sulphur dioxide gave 10.0 per cent. of olefines and aromatic hydrocarbons, which mixture was fractionated several times, and the fractions whose boiling-points corresponded to the boiling-points of benzol, toluol, and xylol were nitrated in the usual manner, water added, and the crude crystalline mass thus obtained recrystallized several times from alcohol. We obtained in this way 1-, 3-dinitrobenzol, melting-point 90° C.; also 2-, 4-dinitrotoluol of melting-point 70° C., and 2-, 4-, 6-trinitrometaxylol, melting at 182° C.

Since relatively little gas is evolved when distilling under 100 pounds pressure, and since the gas evolved contains not more than 4.4 per cent. hydrogen, it appears highly improbable that the aromatic hydrocarbons in question are produced, either directly or indirectly, by a process of splitting off of hydrogen. Since benzol and a few of its simpler homologues have been found in all petroleums which have been thoroughly examined, I believe that the occurrence of benzol, toluol, and xylol in the gasoline made by cracking heavy oils under the conditions described above is to be explained by the splitting or "cracking" of high-boiling complex hydrocarbons,[30] containing the phenyl radicle, for example, such as $C_6H_5.C_{10}H_{19}$, which would be the empirical formula for a phenyl derivative of the naphthene $C_{10}H_{20}$.

---

[30] Jones and Wheeler (*J. Chem. Soc.*, 1914, 2562) have shown that hydrocarbons of the aromatic series are produced in the distillation of coal at 350° C., or below the temperatures at which hydrogen is split off. They suggest that aromatic compounds may be formed by reactions such as the following:



Naphthalene

Further evidence in support of this hypothesis is found in the fact that gasoline made by cracking Oklahoma reduced oil by anhydrous aluminum chloride contains a relatively large percentage of benzol, toluol, and xylol. It is known that the higher benzol homologues are broken down by aluminum chloride. A hydrocarbon of the type $C_6H_5C_{10}H_{21}$ would therefore be expected to yield a mixture of decomposition products containing a small percentage of benzol. One litre of the gasoline made by cracking with $AlCl_3$ was extracted four times with liquid sulphur dioxide, one pound being employed for each successive extraction. The gasoline was cooled to −15° C. and thoroughly shaken with the liquid sulphur dioxide in a large Dewar flask. From one litre of this gasoline we obtained 325 c.c. soluble in liquid sulphur dioxide, which yielded the following:

Fraction	Volume	Result of nitration
45°– 90° C.	75 c.c.	3.6 g. dinitrobenzol
90°–120° C.	85 c.c.	13.8 g. dinitrotoluol
120°–145° C.	55 c.c.	39.6 g. trinitroxylol

This hypothesis is further supported by our finding that pure paraffin, on cracking by distillation under 100 pounds pressure, yields gasoline free from benzol hydrocarbons, and, on the other hand, synthetic phenyl-paraffins are broken down by cracking, as in pressure distillation or by heating with aluminum chloride, giving benzol and its simpler homologues among the reaction products.

The phenyl paraffin was prepared by chlorinating ordinary white commercial paraffin until the gain in weight was equivalent to that required by the formation of the monochloride, the paraffin being considered as a mixture of hydrocarbons of the mean molecular weight corresponding to $C_{24}H_{50}$. This chlorinated product was dissolved in about four times the quantity of benzol required by the reaction and treated with 7 per cent. anhydrous aluminum chloride at room temperature. After standing six hours the mixture was warmed to 80° C., until HCl was no longer evolved. The excess benzol was completely removed by distillation with steam, and the product separated from water and dried. To 500 grammes of this product 35 grammes anhydrous of aluminum chloride were added and the mixture strongly heated for four hours, the reaction product being partly refluxed back into the distilling flask. On rectifying the distillate, 55 c.c. of benzol, boiling-point 78° to 85° C., and 11 c.c. of toluol, boiling-point 105° to 115° C., were obtained, which products were further identified by conversion into the dinitro-derivatives.

Two and one-half kilos of the synthetic phenyl paraffin, from which free benzol had been carefully removed, were subjected to distillation at 75 pounds pressure during a period of three hours. The distillate, 1500 c.c., was fractionated, and the fractions, 70° to 100° C., 100° to 115° C., and 115° to 145° C., examined for aromatic hydrocarbons by nitration.

Fraction	Volume in c.c.	Grammes dinitro-derivative
70°–100° C.	112	25 dinitrobenzol
100°–115° C.	150	40 dinitrotoluol[31]
115°–145° C.	272	

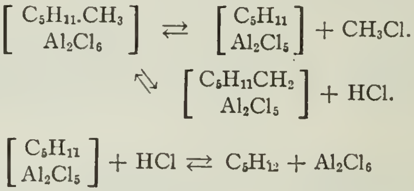
There are, of course, other conditions in which aromatic hydrocarbons are formed by complex reactions which take place at much higher temperatures. Such conditions obtain in the Hall process carried out at about 650° C., and in the manufacture of Pintsch gas at about 900° C. Abundant evolution of gas and separation of carbon occur under these conditions.

When heavy petroleum oils are heated with anhydrous aluminum chloride, cracking occurs with the formation of gaseous hydrocarbons and gasoline and kerosene, and, if the higher boiling oils are refluxed back into the still, yields of 15 to 25 per cent. gasoline may be obtained, depending upon the conditions. This process has been recently patented. The gasoline made by this process is practically free from unsaturated hydrocarbons. Most of the sulphur present in the original oil is evolved as hydrogen sulphide, which may be removed from the distillate by washing with alkali. The gasoline so made is very sweet in odor and very stable to light and air. I have found that the characteristic odor of most commercial gasoline is in part due to traces of naphthenic acids, which may be isolated as the sodium soap by treatment with metallic sodium. The aluminum chloride gasoline is free from this odor; in fact, we have found that ordinary gasoline to which 2 per cent. of Russian naphthenic acids were added was completely deodorized by slowly distilling with aluminum chloride.

---

[31] This dinitrotoluol was recrystallized, obtaining the pure product, melting-point 70.0° C., thus proving its identity beyond any question. In preparing the original phenyl paraffin C. P. benzol was employed.

In the cracking of hydrocarbons with aluminum chloride the nature of the reaction is obscure. The formation of definite compounds of hydrocarbons with aluminum chloride has been shown repeatedly. In view of this fact, and also that free hydrogen chloride (or hydrogen bromide when aluminum bromide is employed) is claimed to facilitate the cracking of certain hydrocarbons, the following series of reactions have been proposed to account for the phenomena:



$$\begin{aligned} \begin{bmatrix} C_5H_{11}.CH_3 \\ Al_2Cl_6 \end{bmatrix} &\rightleftarrows \begin{bmatrix} C_5H_{11} \\ Al_2Cl_5 \end{bmatrix} + CH_3Cl. \\ &\nwarrow\!\!\searrow \begin{bmatrix} C_5H_{11}CH_2 \\ Al_2Cl_5 \end{bmatrix} + HCl. \\ \begin{bmatrix} C_5H_{11} \\ Al_2Cl_5 \end{bmatrix} + HCl &\rightleftarrows C_5H_{12} + Al_2Cl_6 \end{aligned}$$

It has been shown that in the practice of the method for the manufacture of gasoline the coke, which is formed in relatively large amount, may be kept scraped free from the still bottom by a mechanical stirring device.

By way of *résumé,* it should again be pointed out that, while a very large number of patents have been granted describing processes for the manufacture of gasoline from heavy petroleum oils, it should be borne in mind that it is almost impossible to decompose heavy petroleum oils without the production of more or less low-boiling hydrocarbons, no matter what method is employed, provided a suitable temperature, say 380° C. to 450° C., prevails somewhere in the series of operations. The chief difficulty in large-scale operation is the deposition of coke. In view of the public and private history of many so-called discoveries in this field, the heralding of any one process as being the best would at this time be premature. Undoubtedly several years must yet elapse before anything like a standard practice will have been evolved, and that company having had the most experience with large-scale operation will, by the various improvements introduced as a result of persistent, patient trial and experience, undoubtedly dominate the field for longer than seventeen years.

THE TRANSFORMATION OF COLOR-MIXTURE EQUATIONS FROM ONE SYSTEM TO ANOTHER.*

BY

HERBERT E. IVES, Ph.D.,

Physical Laboratory, The United Gas Improvement Company.
Member of the Institute.

The reduction of color specification and measurement to the fewest possible terms has been done, to a limited extent, by the use of two systems of color analysis, each involving three factors. The first method is the trichromatic, in which the color in question is matched by a mixture of three primaries, a red, a green, and a blue. The other is the monochromatic, in which the color is matched by a mixture of a spectrum hue and white, and is defined in terms of its hue, saturation, and luminosity.

While each of these systems is theoretically simple, both become undesirably beset with complications and difficulties when put into practice. Putting aside for the present those difficulties caused by the differences in color vision existing between different individuals, attention may be directed here to three of the problems met with in using these two systems of color measurement. In regard to the trichromatic system, it is to be noted that a very large number of sets of primaries may be chosen, each set resulting in a different set of mixture proportions. In regard to the monochromatic system, it is to be noted that the measurement of one of the elements (namely, luminosity) presents great practical difficulty. The third point, concerning each method equally, is that measurements made by one system have practically never been so transformed as to be directly comparable with similar measurements on the other.

The second of these points—the difficulty of measuring the luminosity factor—is merely noted here. Assuming that it can be met by some acceptable means, the remaining two points present the problem to be handled in the present paper. How can measurements on one trichromatic system be transformed to another system? How can measurements on any trichromatic system be transferred to the monochromatic system and *vice versa?*

---

* Communicated by the Author.

The material for such transformations is to be found in the writings of Abney [1] and of Koenig,[2] dealing with the methods of obtaining the fundamental color sensations. The fact that such transformations are possible and, what is more, necessary, has been frequently overlooked in color measurements that have been published, notably of illuminants. For this reason, and because some interesting light is thrown on the whole question of color measurement by attempting the coördination of the various systems, a brief presentation of the problem is thought warranted, even though little essentially new is developed.

THE COLOR-MIXTURE PYRAMID.

The approach to the problem will here be made through what seems to the writer the clearest method of representing the facts of color mixture; namely, by a space diagram—the color pyramid. A large number of pyramids can be constructed, depending upon whether the coördinates are rectangular or otherwise, and also upon the values of the units taken along different axes. A complete and general treatment of the problem would include all of the possible pyramids, and the relations between them—a complicated problem in solid analytic geometry. For the sake of simplicity a few special cases only will be taken; these, however, are sufficient to meet the practical problems of color measurement.

Imagine a three-color mixture instrument, whose primaries are three spectral wave-lengths, red, green, and blue. Let the primaries be taken in such relative proportions that their mixture makes white. Let these quantities of red, green, and blue be each given the scale value unity. Let the quantity of red in any mixture be represented by a length taken along the X axis of a system of rectangular coördinates, the amount of green by a length taken along the Y axis, and the amount of blue similarly along the Z axis.

Under these conditions we have a number of important relations:

1. Every mixture of red, green, and blue (*i.e.,* every color) is represented by a point in space.

2. The series of grays from black to white is represented by

the straight line whose equation is $R=G=B$. All series of colors of the same hue, but varying luminosity, are represented by straight lines drawn from the origin of coördinates (black).

3. All colors resulting from the positive addition of the three primaries lie inside a cube, one of whose corners represents black, the opposite corner white, the others the red, green, blue, yellow, purple, and blue-green obtained by taking the three primaries in unit quantity singly and in pairs.

4. The color resulting from the mixture of any two is obtained by completing the parallelogram of which two sides are furnished by the lines joining the origin and the points representing the colors. The hues of all mixtures of two hues are given by the straight lines lying in the plane bounded by the two lines representing the original hues.

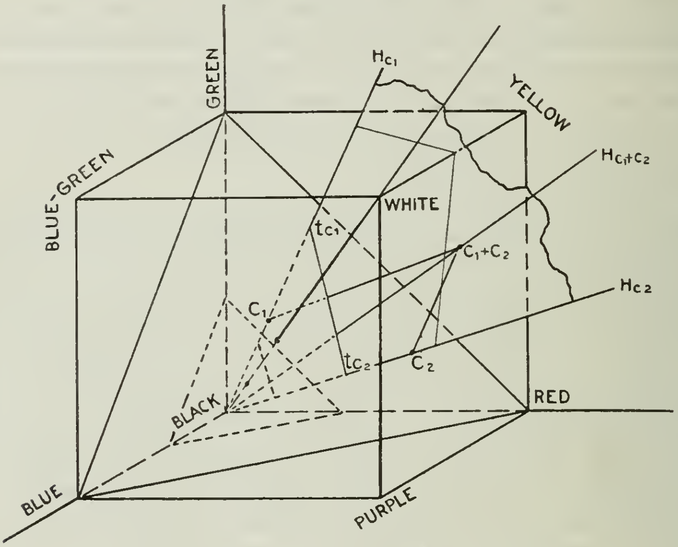
5. Sections of the color pyramid taken normal to the black-white line are equilateral triangles and give all colors composed of the same quantity of the primaries. The size of a triangle is proportional to the quantity of red, green, and blue in any color represented by a point in the triangle. The relative amounts of red, green, and blue are given by the vertical distances of the point representing the color from the sides opposite the vertices representing each primary (these vertical distances being proportional to the three vectors from the origin to the point in the triangle plane). In these color triangles the hues of mixtures of two colors are on the straight line joining the two color points (this line being the intersection of the hue plane given above with the plane of the triangle). *Complementary colors* are colors whose connecting line passes through white, and which, therefore, may be mixed to produce white.

These relations are shown pictorially in Fig. 1.

It should not be necessary to point out that these relations apply only to color mixtures and not at all to mere plots of the relative energy values at three wave-lengths, or through three-color screens, as has been erroneously assumed in several instances.[6]

A restriction, applying chiefly to relation 2 but affecting all the discussion, may be mentioned here and kept in mind in all that follows. This is that we are to deal only with a range of intensities in which the Purkinje effect is not noticeable. The effect of this phenomenon is to twist the hue lines as they approach the origin of coördinates. A section (color triangle) near the origin, corresponding to low luminosity, will show a set of hues such as the spectrum shifted from their normal positions. We shall in this discussion avoid the complications entering at low illuminations in the same manner that they must be escaped in practical measurement; that is, by considering all the measurements made at one fixed brightness or near it.

FIG. 1.



Spacial Representation of Three-color Mixture Phenomena.
Axes =primaries.
Vertices of cube =mixtures of primaries taken singly, in pairs, and all together.
C_1 and C_2, arbitrary colors.
C_1+C_2, color resulting from mixture of C_1 and C_2.
Hc_1, Hc_2, Hc_1+Hc_2, hue lines of colors C_1, C_2, and C_1+C_2.
tc_1, tc_2, hues of colors C_1 and C_2 in color triangle.
tc_1, tc_2 =trace of hue line plane on color triangle.

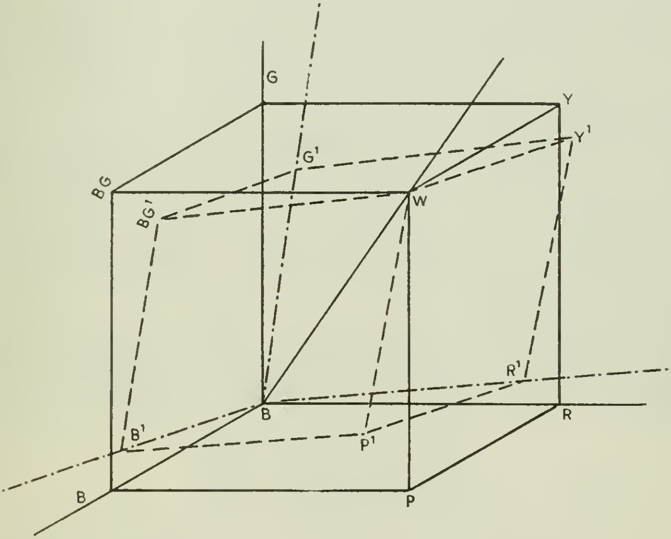
TRANSFORMATION FROM ONE SET OF PRIMARIES TO ANOTHER.

Let us assume two-color mixture instruments " A " and " B," using as primaries two different sets of red, green, and blue. Let the problem be to transform measurements made by instrument " B " into the values which would be obtained by instrument " A." Or, put differently, let us find how instrument " A " must be set to exhibit the color known only by its value as measured by " B."

For the solution of this problem it is necessary to know the values of the primaries of " B " on the scale of instrument " A." These may be obtained either by direct measurement, or by calculation from the color-mixture curves of the spectrum, using spectrophotometric data. The graphic methods of obtaining the mixture values of any color of known spectral composition will be dealt with presently, so that we need note now only that the "A" values of the "B" primaries can be obtained, and proceed from that point.

As measured, these "B" primaries may already be in the proportions that mix to make the standard white to which both instruments are referred. If so, each primary may be placed at once in its position in the rectangular "A" pyramid. By the construction of the primary hue lines, and the parallels representing the additions of the primaries, a figure is obtained similar to the cube described under relation 3, containing all the colors obtainable by the positive addition of the "B" primaries. The new figure is not, however, a cube. The relation of these two figures, the cube and its equivalent, is shown in Fig. 2.

FIG. 2.



Transformation from One Set of Primaries to Another.
R, G, and B = primaries of System A.
R', G', and B' = primaries of System B, plotted in rectangular representation of System A.
Vertices of cube = mixtures of primaries of System A, singly, in pairs, and all together.
Vertices of parallelopiped = mixtures of primaries of System B, in their position in System A.

If we assume ourselves provided with an actual model of these two figures, having the same black and white apices, the process of transforming " B " measurements into " A " units is simple. It is only necessary to note that with instrument " B " the primary hue edges of the enclosing figure have been, as is customary, assigned the value unity. If then we take any " B " measurement and multiply the red, green, and blue values by those values which the corresponding primary hue edges have in the figure " A," the resultant values are in shape for plotting in the " A " pyramid by the ordinary process of addition of vectors.

It is probably the more common case that the " B " primaries are not determined in the exact proportions (on the " A " scale) in which they mix to make the standard white, but only by their hue lines; *i.e.,* their position in a color triangle. In that case it becomes necessary to determine these proportions; that is, the section of the " A " pyramid in which each lies. This may be done best algebraically, and the procedure leads as well to the complete transformation equations which it is our object to obtain.

Let us denote the primaries of " A " by the letters R, G, and B, and those of " B " by the letters R', G', and B'. Any color is then described by equations of the form $C = \beta R + \beta' G + \beta'' B$ and $C = \alpha R' + \alpha' G' + \alpha'' B'$, where β, β' β'', α, α', α'', are coefficients of maximum value unity.

We suppose that the primaries of " B " are known as lying on the hue lines of the " A " pyramid in accordance with the relations

$$\begin{aligned} R' &= x\,(aR + a'G + a''B) \\ G' &= y\,(bR + b'G + b''B) \\ B' &= z\,(cR + c'G + c''B) \end{aligned} \qquad (1)$$

where a, a', a'', b, b', b'', c, c', c'' are color triangle coördinates of the " B " primaries.

Since the standard whites of the two instruments are the same, we have

$$R' + G' + B' = R + G + B \qquad (2)$$

Adding the three equations (1), substituting (2) for the summation of the left-hand side, and equating coefficients of like colors, we have

$$\begin{aligned} xa + yb + cz &= 1 \\ xa' + yb' + zc' &= 1 \\ xa'' + yb'' + zc'' &= 1 \end{aligned} \qquad (3)$$

Solving these equations for x, y, and z, we obtain

$$x = \frac{-(bc' - b'c)(c'' - c) + (c' - c)(bc'' - b''c)}{(ac' - a'c)(bc'' - b''c) - (bc' - b'c)(ac'' - a''c)} \tag{4}$$

and similar terms for y and z. Substituting these in (1), we finally obtain the equations:

$$\begin{aligned} R' &= mR + nG + pB \\ G' &= m'R + n'G + p'B \\ B' &= m''R + n''G + p''B \end{aligned} \tag{5}$$

where $m = xa$, $n = xa'$, etc.

In order to transform any color-mixture equation obtained with instrument "B" into its value on instrument "A," the process is simply to multiply the red, green, and blue readings by the values of R', G', and B' given by equation (5).

Geometrically the meaning of these transformations is that we have made a non-cubical projection of the cube of the system "B" onto the axis of system "A," as shown in Fig. 2.

A numerical example of a transformation from one trichromatic system to another is afforded by the determination of the fundamental sensation values corresponding to readings taken with an F. E. Ives colorimeter.[3] (The fundamental sensations are the primaries of a trichromatic system to be discussed later.)

The values of the colorimeter primaries as derived through spectrophotometric data and Koenig's data for the distribution of the sensations through the spectrum are:

	Red sensation	Green sensation	Blue sensation
Red primary =	.780	.220	.000
Green primary =	.335	.580	.085
Blue primary =	.095	.019	.886

These coefficients, representing, as they stand, positions on a sensation color triangle, correspond to the coefficients a, a', b, c, etc., in (1).

Solving for x, y, and z, and then for m, n, p, etc., we obtain finally

	Red sensation	Green sensation	Blue sensation
Red primary =	.406	.115	.000
Green primary =	.500	.866	.127
Blue primary =	.094	.019	.873
	1.000	1.000	1.000

Suppose now a color is measured by the colorimeter as being

Red	.50
Green	.30
Blue	.10

By the use of the figures just obtained we find the sensation values to be

Red sensation	.362
Green sensation	.319
Blue sensation	.125

The different values of the mixture proportions of these two sets of primaries illustrate clearly the point emphasized in the introduction, that proper transformations are necessary before comparisons are permissible between measurements made by different three-color mixture instruments.

SPECIFICATION BY HUE, QUANTITY, AND QUANTITY OF WHITE.

We have just treated one of the practical systems of color measurement, the trichromatic, in its commonest form, where the three primaries are arbitrarily given equal values. It is our purpose to treat as well the other common method of color measurement, the monochromatic, in its most useful form, where the units are hue, luminosity, and luminosity of the white mixed with the hue. In going over from the trichromatic to the monochromatic it is desirable to treat two intermediate systems, theoretically on a par with these, but not in use. These are the system of specification by hue, quantity, and quantity of white, and the trichromatic system in which the primaries are assigned their luminosity values.

By "quantity" is here meant the sum of the coefficients of the three primaries. Thus the quantity of the color $aR + a'G + a''B$ is $a + a' + a''$.

"Hue" on the hue, quantity, and quantity of white system refers to some definite scale of hues, fixed by some convenient physical reference phenomena, the hues preferably completely surrounding the white centre axis of the pyramid. Such a scale is furnished, for instance, by the spectrum. Assuming such a scale of hues, it follows at once, from the properties of the color pyramid tabulated above, that any color can be formed by the mixture of white and some hue. This hue is the intersecting line of the plane through the color, white, and the cone which forms the hue scale. In the color triangle this hue is found by the intersection of the line joining white and the color with the line representing the hue scale. For illustration, the spectrum hue of any color is obtained from the color triangle by drawing a line through the centre of the triangle and the point representing the color. This line continued cuts the curve representing the spectrum, from which the wave-length of intersection may be read off.

Our problem is to transform a trichromatic measurement to this new system. In order to do this our scale of hues must be definitely known in terms of the mixing proportions of the trichromatic primaries. In the case of the spectrum this means that we must know the mixture curves of the spectrum. For convenience in finding the hue of the color with which we are dealing, the hue scale mixture data should be plotted in a color triangle, as should also the value of the color. This is done quite simply by drawing parallels to the sides opposite each primary vertex, each parallel being distant from the side that fraction of the altitude of the triangle that its corresponding primary quantity is of the total quantity of all the primaries forming the measurement. The intersection of these parallels determines the position of a point of the hue of the color, as already indicated.

The hue having been thus determined, the rest of the problem is the determination of the white quantity.

Let the equation of the color be

$$C = aR + a'G + a''B$$

the total quantity of the color is

$$Q = a + a' + a''$$

The quantity of white given by the instrument with all these primaries utilized to full value is $1 + 1 + 1 = 3$.

To obtain the quantity of white to mix with the hue to match the color we have

$$q(R + G + B) + x(uR + vG + wB) = aR + a'G + a''B \qquad (6)$$

where quantity of white in color $= 3q = W = q \times$ quantity of instrument's maximum white, and the color triangle equation of the hue $= uR + vG + wB$.

Equating coefficients of like colors in (6), we obtain

$$q = \frac{ua' - va}{u - v} = \frac{va'' - wa'}{v - w} = \frac{wa - ua''}{w - u}.$$

We thus have finally

$$Q = a + a' + a''$$

$$W = 3\,\frac{ua' - va}{u - v} = 3\,\frac{va'' - wa'}{v - w} = 3\,\frac{wa - ua''}{w - u} \tag{7}$$

with *h*, the hue, determined by some convenient scale number.

The converse problem, given the hue, the quantity, and the quantity of white, to find the coefficients of the three primaries, is solved from the same equations, giving

$$\begin{aligned} a &= \frac{Qu - \frac{W}{3}(2u - v - w)}{(w + v + w)} \\ a' &= \frac{Qv - \frac{W}{3}(2v - w - u)}{(w + v + w)} \\ a'' &= \frac{Qw - \frac{W}{3}(2w - u - v)}{(w + v + w)} \end{aligned} \tag{8}$$

The interest of this method lies entirely in the fact that the monochromatic system in practical use is one of its special cases. Its practical value is *nil*, for the reason that there is no direct method of measuring the "quantity" of a color. This factor is indeed entirely arbitrary, owing its existence to the practice of calling the amounts of the three primaries equal in white light.

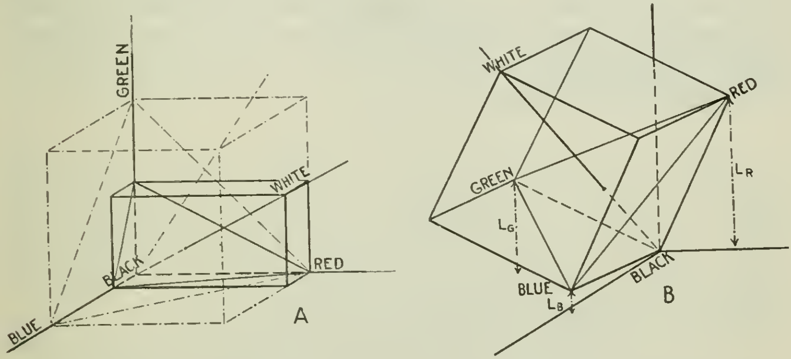
LUMINOSITY RELATIONS IN THE TRICHROMATIC SYSTEM.

While there is no practical direct measure of the "quantity" of a color as above defined, there is a practical measure of a similar common quality of all colors. This is the luminosity, which may be measured directly, and which is the sum of the luminosities of such elements as are combined or mixed to produce the color.

It is possible to determine the luminosity values of a set of trichromatic primaries in the proportions with which they mix to make white, and build up a color pyramid with the luminosity values as the edges. The luminosity values are of quite different relative magnitude from the conventional equality which has heretofore been assigned to the three primaries. As a consequence the mixture figure is no longer a cube, but (if rectangular coördinates are adhered to) a rectangular parallelopiped (Fig. 3 A). In place of the equilateral color triangle it is an irregular triangle, in which, however, white is still represented by the point of intersection of the bisectors of the sides.

This figure, which is the spacial representation of the measurements made with a three-color instrument, when the three primaries are recorded by their luminosity values, is difficult, if not impracticable, to work with. For that reason it will not be treated here. Instead the luminosity relations will be taken care of by ascribing to each primary, on the equal-value method of representation, a luminosity coefficient, with which it is to be multiplied if the luminosity value is desired. This is equivalent to referring all colors to a luminosity reference plane, the luminosity coefficients of the primaries being the sines of the angles made by the primary lines with this plane (Fig. 3 B).

FIG. 3 A. FIG. 3 B.



Methods of Representing Luminosity Relations in the Color Pyramid.

A. By assigning to the three primary lines lengths proportional to the luminosity of the primaries in their white-making quantities. The color cube becomes a rectangular parallelopiped.

B. By assigning to each primary a luminosity coefficient. By this method the convenient cube is retained, being merely tilted with reference to an auxiliary plane.

Introducing the symbol L_G for the luminosity coefficient of a color, we have for the color

$$C = aR + a'G + a''B$$

the relation

$$L_C = aL_R + a'L_G + a''L_B \qquad (9)$$

where L_R, L_G, and L_B are the luminosities of those quantities of the primaries which mix to make white. The luminosity of the color relative to that of the white of the instrument (using its primaries in maximum quantity) is

$$\frac{L_C}{L_W} = \frac{aL_R + a'L_G + a''L_B}{L + L_G + L_B}$$

which may be written, using primed letters, as $L'_C = aL'_R + a'L'_G + a''L'_B$.

It is sometimes necessary to know the luminosity values of a new set of primaries. These are obtained by inserting the luminosity coefficient in equation (5) above.

SPECIFICATION BY HUE, LUMINOSITY AND LUMINOSITY OF WHITE.[4]

We are now in a position to transform color equations from the trichromatic to the only practically used monochromatic system, and *vice versa*. The necessary equations of transformation are obtained by introducing the luminosity coefficients in the derivation of equations (7) and (8).

Thus, given the color

$$C = aR + a'G + a''B$$

we obtain its hue by the use of a color triangle, as described above; we obtain its luminosity as indicated by equation (9); finally, we note that the luminosity of the white component is represented by the equation (7), already derived, since in this instance the luminosity coefficients drop out.

Since it is the usual practice to express the luminosity values in terms of the luminosity of the reference white as unity, we can rewrite equation (7) in the form to be ordinarily used,

$$L'_W = \frac{ua' - va}{u - v} = \frac{va'' - wa'}{v - w} = \frac{wa - ua''}{w - u} \qquad (10)$$

where u, v, and w are the color-triangle coefficients of the hue, and L'_w is the luminosity of the white component in terms of the luminosity of the reference white.

In carrying out the converse process we determine the hue, luminosity, and the luminosity of white by observation. The mixture values of the hue are then found from the color-triangle plot of the hue scale (*e.g.*, the spectrum). Going through the process by which equation (8) was obtained, but carrying along luminosity coefficients, we obtain

$$\begin{aligned}
a &= \frac{uL'_C + L'_W[(w-u)L'_B-(u-v)L'_G]}{uL'_R + vL'_G + wL'_B} \\
a' &= \frac{vL'_C + L'_W[(u-v)L'_R-(v-w)L'_B]}{uL_R' + vL'_G + wL'_B} \qquad \text{(11} \\
a'' &= \frac{wL'_C + L'_W[(v-w)L'_G-(w-v)L'_R]}{uL'_R + vL'_G + wL'_B}
\end{aligned}$$

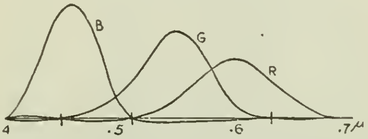
where *u, v,* and *w,* and the primed letters, have the significance above noted.

The data necessary for the transformation from a trichromatic system, of which there are as many as the possible choices of sets of primaries, to a monochromatic system using luminosity values, of which there are as many as there are hue scales, reduce to two sets. We must know the mixture values of the hue scale on the trichromatic system, and we must know the luminosity values of the trichromatic primaries.

THE SPECTRUM.

The only hue scale ever employed in practical color measurement is the spectrum. All the important work on color mixture has been done upon the spectrum. All colors being formed of mixtures of portions of the spectrum, it is necessary to know only the place of the spectrum in any color-mixture system in order to handle all practical problems of color measurement. The chief facts and relationships in regard to the spectrum are summarized below.

FIG. 4.



Diagrammatic Color-mixture Curve of the Spectrum.
The primaries, taken as spectral wave-lengths, are indicated by the short vertical lines. Note the negative values between the primaries.

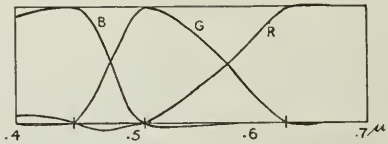
Three-color Mixture Curves on the Equal Primary Basis.—If the spectrum of white light is measured by a three-color mixture instrument a set of mixture curves of the spectrum is obtained. Of these the Maxwell curves are a good example. The areas of the three curves, red, green, and blue, are equal if the mixing quantities of the three primaries to make white are called equal. A diagrammatic set of such mixture curves is shown in Fig. 4. They show the values of *a, a′,* and *a″,* using the symbols of the previous sections. A characteristic of these curves is that for all real primaries, such as spectral colors, the mixture curves have regions of negative values. These negative values indicate that the mixture is less saturated than the spectral hue. The measurement is made in these regions by adding a small quantity of the negatively occurring primary or of white to the color being measured. This matter will be treated in the section dealing with the fundamental color sensations.

Three-color Percentage Curves on the Equal Primary Basis.—Instead of plotting the mixture curves as they are obtained, it is desirable for some purposes (*e.g.*, to assist in plotting the spectrum in a color triangle) to plot the percentage of each sensation at each wave-length. Such a percentage representation is shown in Fig. 5. Using the symbols of this paper, the figure shows values of $\frac{a}{a+a'+a''}$, $\frac{a'}{a+a'+a''}$, and $\frac{a''}{a+a'+a''}$.

The Spectrum in the Color Pyramid.—The white light spectrum is represented in the color pyramid by a curved line, starting at the origin of coördinates, rising to a high value on the red-green and green-blue sides, and returning to the origin near the red-blue side intersections. Mixtures of red and blue are practically missing in the spectrum. As a consequence the spectrum does not form a completely enclosing hue scale, such as was postulated in the discussion of specification by hue and other factors. This introduces the complication in the monochromatic method of specifying purples by the hue which must be mixed with the color to make white, instead of the hue which mixes with white to make the color. This, however, merely means a change of signs in the equation given above, and will be ignored here. The spectrum line is shown diagrammatically in the color pyramid in Fig. 6.

The Spectrum in the Color Triangle.—The spectrum is repre-

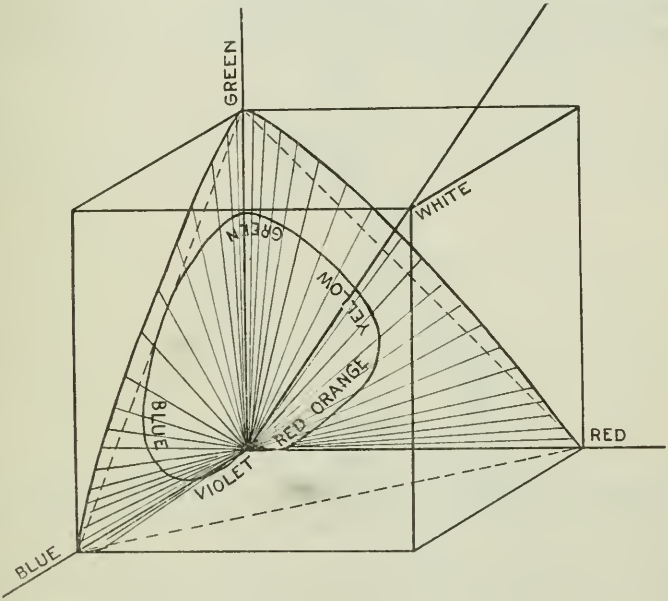
FIG. 5.



Percentage Mixture Curve of the Spectrum.
Relative proportions of the three primaries used at each wave-length, on basis of equal weighting of primaries as mixed to make white light.

sented in the color triangle by the trace of the conical figure formed by the hue lines drawn through the spectrum line in the pyramid. The spectrum is plotted in the color triangle most simply from the percentage diagram shown in Fig. 5. If the altitude of the triangle is taken as the unit, every point in the percentage diagram has a corresponding point in the triangle. (The sum of the perpendicular distances of any point from the three sides of an equilateral triangle is equal to the altitude.) Fig. 7 shows a diagrammatic color-triangle spectrum plot. The relative quantity of red is given by the perpendicular distance of any point from the side opposite the red vertex, and similarly for the other primaries. The hues between red and blue are missing in the spectrum, as noted. The spectral hue of any color is obtained by drawing the line from white through the point representing the percentage composition of the color until it intersects the spectrum line.

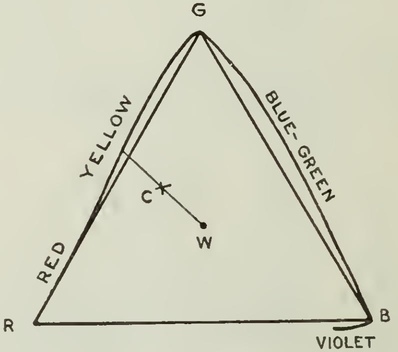
FIG 6.



The Position of the Spectrum in the Color Pyramid.

The Determination of Mixture Values from Spectrophotometric Data.—One of the most useful services of a set of mixture curves of the spectrum is to reduce spectrophotometric data to mixture values. In the case of transmissions of absorbing media it is merely necessary to multiply the mixture-curve ordinates by the transmission values at each wave-length.[3] The areas of the three reduced curves give at once the mixture values of the transmitted light. In the case of light not obtained by a process of absorption it is necessary to know the energy distribution of the light and compare it with the energy distribution which has been chosen for "white," and then to go through a multiplication process with the mixture-curve ordinates in a manner exactly parallel with the procedure just outlined. By the methods already given, these three-color mixture values may be transformed to hue, luminosity, and saturation values, these latter thus demanding two steps from the spectrophotometer data.

FIG. 7.



The Position of the Spectrum in a Color Triangle.

The spectrum lies in general outside the triangle whose primaries (vertices) are spectral wave-lengths. The spectral hue of any color (c) is obtained from the intersection of the line through the white centre, the color, and the spectrum line.

Three-color Mixture Curves on a Luminosity Basis.—If, instead of calling the quantities of the three primaries which make white equal, we assign to them their luminosity values, a set of mixture curves results in which the three curves are of quite different areas. An important characteristic of this set of curves is that their summation gives the luminosity curve of the spectrum. The characteristics of mixture curves on a luminosity basis are shown in the sensation curves of Fig. 12. The ordinates, using the symbols of this paper, are aL_R, $a'L_G$, and $a''L_B$.

Three-color Mixture Percentage Curves on Luminosity Basis.

—In a similar fashion to the percentage mixture curves on the equal primary basis there may be plotted percentage curves on the luminosity basis.

The ordinates of such a plot are

$$\frac{aL_R}{aL_R + a'L_G + a''L_B}, \frac{a'L_G}{aL_R + a'L_G + a''L_B}, \text{ and } \frac{a''L_B}{aL_R + a'L_G + a''L_B}.$$

The Luminosity Curve of the Spectrum.—Since the summation of the mixture curves of the spectrum on the luminosity basis is the luminosity curve of the spectrum, it is of importance to have this latter curve determined with accuracy by independent means. In Fig. 12 is given a spectral luminosity curve for the white light spectrum. (The white light luminosity curve is obtained by multiplying the ordinates of the equal energy luminosity curve [5] by that energy distribution which is assumed to represent white light. The author uses for this the distribution in a black body of 5000° absolute, as calculated from the Wien equation.[3])

The Luminosity Values of Trichromatic Primaries Derived from Mixture Curves and Luminosity Curve.—The most usual form in which mixture curves of the spectrum are obtained and recorded is on the basis of equal scale values for the three primaries. Certain of the transformations which have been dealt with require the luminosity values of the primaries. The problem is therefore presented of determining these luminosity values. For this purpose (unless a process of direct measurement is resorted to), we use the luminosity curve of the spectrum, remembering that the summation of the three ordinates representing the primaries should equal the luminosity ordinate when each primary is assigned its luminosity value.

Since we have three unknown factors, we obtain the solution by data from three points in the spectrum. The following three equations are formed:

$$L_{\lambda 1} = a_1L_R + a_1'L_G + a_1''L_B$$
$$L_{\lambda 2} = a_2L_R + a_2'L_G + a_2''L_B$$
$$L_{\lambda 3} = a_3L_R + a_3'L_G + a_3''L_B$$

where $L_{\lambda 1}$, $L_{\lambda 2}$, and $L_{\lambda 3}$ are taken from the luminosity curve, the a's from the mixture curves, and L_R, L_G, and L_B are the coefficients to be determined.

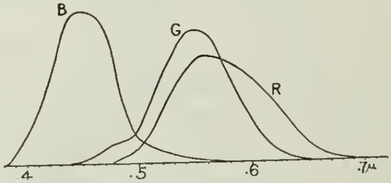
Solving, we obtain:

$$
\begin{aligned}
L_R &= \frac{-(a_1'a_2''-a_2'{}_1'')(L\lambda_1 a'_3 - L\lambda_3 a'_1) + (L\lambda_1 a_2'' - L\lambda_2 a_1'')\,(a'a_3'' - a_3'a_1'')}{(a_1a_2''-a_2a_1'')(a_1'a_3''-a_3'a_1'')-(a_1'a_2''-a_2'a_1'')(a_1a_3''-a_3a_1'')}\\
L_G &= \frac{-(a'_2a''_3-a'_3a''_2)\,(L\lambda_2 a_1''-L\lambda_1 a_2'')+(L\lambda_2 a_3''-L\lambda_3 a_2'')\,(a_2'a_1''-a_1'a_2'')}{(a_2a_3''-a_3a_2'')(a_2'a_1''-a_1'a_2'')-(a_2'a_3''-a_3'a_2'')(a_2a_1''-a_1a_2'')} \qquad (13)\\
L_B &= \frac{-(a_3'a_1''-a_1'a_3'')(L\lambda_3 a_2''-L\lambda_2 a_3'')+(L\lambda_3 a_1''-L\lambda_1 a_3'')(a_3'a_2''-a_2'a_3'')}{(a_3a_1''-a_1a_3'')(a_3'a_2''-a_2'a_3'')-(a_3'a_1''-a_1'a_3'')(a_3a_2''-a_2a_3'')}
\end{aligned}
$$

These various relations between the properties of the spectrum which have now been developed suffice for all the transformations from system to system which are ordinarily to be met with. In addition, as will be seen, they furnish criteria by which the accuracy of the determinations of spectrum mixture curves may be tested.

The Elementary and Fundamental Color Sensation Curves.—It has been pointed out that there are as many trichromatic systems of color measurement as there are possible choices of sets of red, green, and blue that will mix to make white. It has also been pointed out that the color-mixture curves of the spectrum, which is the purest hue scale obtainable, always have regions of negative values. These two facts have suggested, first, that the real primary "sensations" lie outside the spectrum, and, second, that these primary "sensations," if they can be determined, constitute the set of primaries to which all mixture data should be transformed. It is clear, from what has gone before, that a set of mixture data can be transformed to any other set of primaries. From the color-triangle plot of the spectrum, using any real primaries, as in Fig. 7, it is evident that we can choose a set of primaries lying outside the triangle such that the spectrum will lie entirely within the new triangle formed by joining the new primary points. When the data have been transformed

FIG. 8.

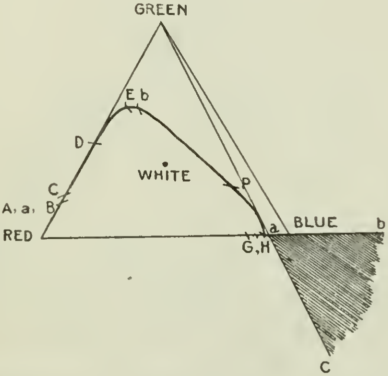


The Elementary Sensation Curves as Determined by Koenig for His Own Eye. These differ from the mixture curves in having no negative values.

to this new set of primaries the corresponding color-mixture curves no longer have negative values. Curves constructed from the mixture data so as to have no negative regions have been called by Koenig " Elementary sensation curves." The elementary sensation curves found by Koenig for his own eye are shown in Fig. 8. (The sensation curves obtained by Abney are " Elementary " sensation curves.)

To this criterion for fundamental character Koenig then added another. A large number of selections of primaries is possible which shall give no negative values to the spectrum. What guide is there for the selection of the true fundamentals? This Koenig found from mixture measurements on color-blind observers. By a certain choice of these possible primaries lying outside the spectrum it was found that the chief types of color-blindness reduced to absence of one or the other of these primaries. The final choice of primaries is shown by the color sensation triangle Fig. 9, in which the spectrum is plotted for reference. Fig. 10 shows the mixture curves of these primaries, or the " Fundamental sensation curves." (The mean values for Koenig's group of observers are plotted.)

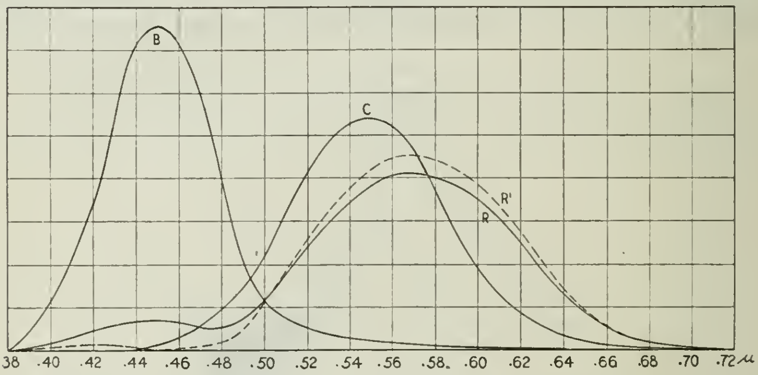
FIG. 9.



The Fundamental Sensations Represented in a Color Triangle.
Cross-hatched area is region within which blue primary may be chosen without conflict with the experimental data.

Assuming the correctness of these curves, we have here the fundamental reference frame to which all color measurements are properly reduced. The methods for doing this have already been indicated. Spectrophotometric data are directly reducible by the multiplication of ordinates. Three-color mixture data are reducible, once the sensation values of the primaries are known, and these are obtainable from spectrophotometric values. In order to determine the sensation values from measurements of hue, luminosity, and luminosity of white, it is necessary to know the luminosity values of the three sensations. These were not considered or measured by Koenig, but can be obtained by the methods given above. Their determination brings up points of some interest, to which a separate section will be devoted.

FIG. 10.



The Fundamental Sensation Curves of the Spectrum.
Full lines mean values of Koenig's five observers. Dashed line, new red curve, obtained by different choice of blue primary dictated by luminosity considerations.

THE LUMINOSITY VALUES OF THE KOENIG FUNDAMENTAL COLOR SENSATIONS.

In order to obtain the luminosity values of the fundamental sensation primaries, equations (12) were used, the coefficients at any wave-length being read off the sensation curves and the luminosities of the same wave-lengths off the luminosity curve of the white light spectrum. Two peculiarities were found in the values obtained: First, the values for the luminosities of the sensations are not constant, but differ with the wave-lengths used; and, second, the luminosity value of the blue sensation comes out *negative*. For instance, using wave-lengths 0.63μ, 0.50μ, and 0.46μ, the luminosity values are (in arbitrary units):

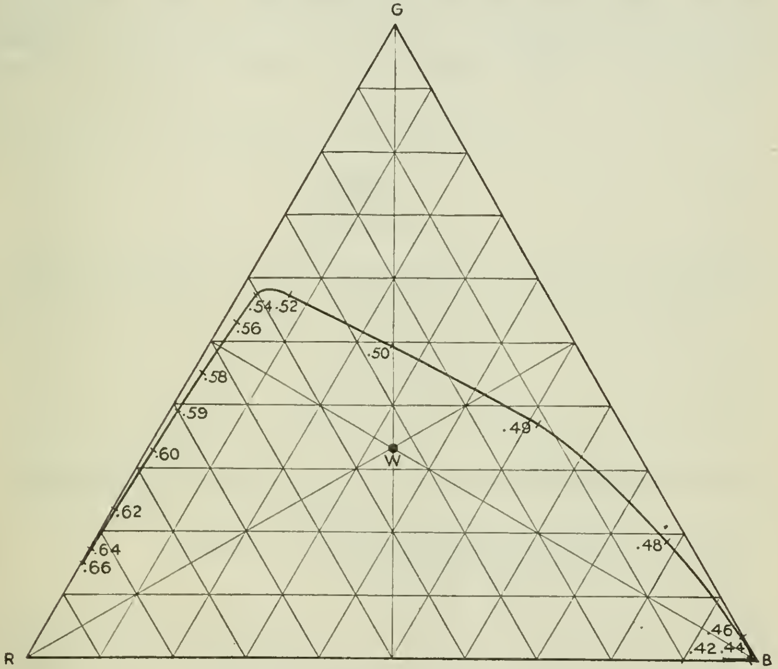
$$L_R = .395$$
$$L_G = .578$$
$$L_B = -.028$$

Using wave-lengths 0.60μ, 0.052μ, and 0.46μ, the luminosity values are:

$$
\begin{aligned}
L_{R} &= .483\\
L_{G} &= .491\\
L_{B} &= -.026
\end{aligned}
$$

The reason for these peculiarities is found, upon inspection of the sensation curves, to be due to the existence of the second maximum of the red sensation in the blue of the spectrum. *This maximum as determined by Koenig is of such elevation that no positive luminosity values for the blue sensation will satisfy the conditions, at the same time that the red sensation is given adequate values to take care of the red end of the spectrum.*

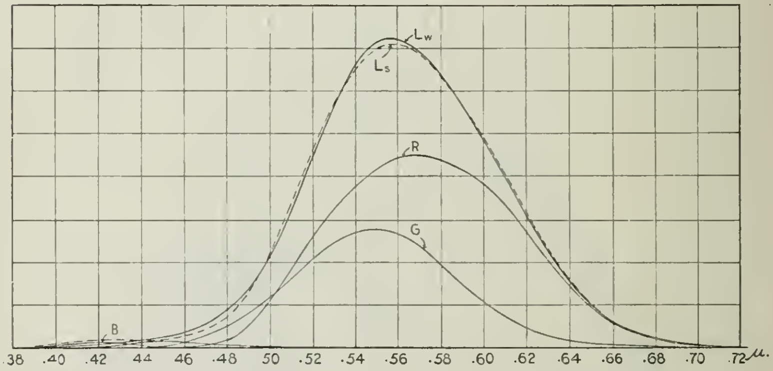
FIG. 11.



The Fundamental Color Sensation Triangle.
The new red curve is used in plotting this.

This second maximum of the red sensation owes its existence to the fact that the blue primary was chosen quite far outside the spectrum, as is shown by the sensation color triangle. Now the interesting thing is that this position was fixed upon, as Koenig says, "*völlig willkürlich.*" Fig. 9, reproduced from Koenig's original paper, shows the sensation equilateral triangle as adopted, but with the region indicated, by the cross-hatched area *abc,* within which the blue primary might be placed anywhere and still be in agreement with the experimental data. The assignment of luminosity values to the sensations actually constitutes a new criterion for the correctness of the fundamental curves, additional to those used by Koenig. (It is of interest to note that Koenig, in a footnote to his paper on "Young's Color Theory" in his collected works, speaks of having realized, since its original publication, that valuable light would be thrown on the shape of the sensation curves by heterochromatic brightness equations.)

FIG. 12.



The Fundamental Sensations in Their Luminosity Values.
R, *G*, and *B* = sensation curves plotted according to their luminosity.
L_S = summation of the three sensation curves.
L_W = white light spectrum luminosity curve.

The failure of Koenig's curves to yield consistent luminosity values in their present form suggests the desirability of re-plotting his data with a different choice of the wholly arbitrary factor —the blue primary—such that this new criterion will be satisfactorily met. Any point between *b* and *a* in Fig. 9 may be tried, but the very low luminosity of this part of the spectrum suggests the point *a* itself as the most probable. The transformation to a new set of primaries, comprising the old red and green and the new blue defined by the point *a,* follows, being merely a special case of the transformation methods already described.

Let the coefficients of any wave-length on the Koenig curves be a, a', a'', and let the new unknown coefficients be x, y, and z. Then we have

$$aR + a'G + a''B = xR + yG + zB$$

We have also, since both systems are referred to the same white, $R' + G' + B' = R + G + B$.

We have from the color triangle that the hues of the new red and green primaries are the same as the Koenig sensations; and we have the hue of the new blue primary fixed by the ratio of its blue and red sensation components, which ratio we shall call $\frac{b}{c}$. These facts are expressed in the equations:

$$R' = mR$$
$$G' = nG$$
$$B' = p(bB + cR)$$

By substituting in the last equation we obtain, by equating coefficients of like terms, values of m, n, and p, and, finally,

$$R' = \left(1 - \frac{c}{b}\right)R$$
$$G' = G$$
$$B' = B + \frac{c}{b}R$$

Substituting in the first equation for R', G', B' we get

$$y = a'$$
$$z = a''$$
$$x = \frac{a - a''\frac{c}{b}}{1 - \frac{c}{b}}$$

This gives us the final relation that any color represented in the Koenig curves by the expression

$$aR + a'G + a''B$$

is given in the new system by the expression

$$\frac{a - a''\frac{c}{b}}{1 - \frac{c}{b}}R' + a'G' + a''B' \qquad (14)$$

The only coefficient which is changed by this particular transformation is that of the red curve points.

The value of $\frac{c}{b}$ to be used was obtained by drawing the line from the green vertex of the sensation triangle through the point nearest the green-blue side obtained by the mean of Koenig's group of observers. From its intersection on the red-blue line the value for $\frac{c}{b}$ is 0.092, giving a working value of $\frac{a-.092a''}{.908}$ for the new red coefficient.

In Fig. 10 are shown the Koenig sensation curves, plotting the mean values of all his observers, and the new red curve, obtained from these by the transformation just indicated. In Fig. 11 the spectrum is shown in the new color triangle.

The new curves should meet the additional criterion that consistent luminosity values may be assigned them. This point was tested by solving equations with three sets of three wave-lengths. These gave positive and fairly consistent values for the luminosities of the three sensation primaries. Assigning to each the mean value obtained, the three curves were plotted, their summation made and compared with the luminosity curve of the white light spectrum. Some changes were then made to make the agreement best in the best-determined and most important parts of the luminosity curve, giving as the final values,

Luminosity of red sensation	.648
Luminosity of green sensation	.336
Luminosity of blue sensation	.016

In Fig. 12 are shown the three new sensation curves in their luminosity values, their summation, and the white light luminosity curve.

Remembering that different groups of individuals determined the various curves which are compared, that the variations among the observers of the sensation curves are quite large, and that various assumptions have been made, such as the energy distribution in white light, it is evident that the agreement is quite good. It certainly lies within the uncertainty of determination of both sensation and luminosity curves. These luminosity values are very nearly the same as those assigned by Abney to his elementary sensations, which gives some additional weight.

The subject matter of this section may be summarized as to its practical and theoretical results. On the practical side luminosity values have been found for the fundamental sensation primaries, completing the necessary data for the transformation of all practical color measurements to sensation values, and *vice versa.* On the theoretical side an additional condition which must be met by sensation curves has been applied to the Koenig curves, resulting in a slight modification of their form.

With regard to the position of the blue primary, which was left undetermined by Koenig's two criteria, the luminosity criterion, of course, fixes only the region within which the luminosity value shall be positive, consequently the true position is still somewhat in doubt. Probably the only means of fixing this exactly would be the isolation and study of the optical properties of the "red" photochemical substance of the retina, as Koenig has suggested.

SOME NUMERICAL EXAMPLES OF COLOR EQUATION TRANSFORMATIONS.

Color measurements of the same colors made by both the trichromatic and monochromatic methods, suitable for illustrating the use of equations (10) and (11), are few. The only measurements known to the writer which can be used are some upon illuminants, the monochromatic by Jones,[4] the trichromatic by the writer.[3] The latter, reduced to Koenig sensation values, are referred to a black body at 5000° as white, the former to clear sunlight. A number of accurately specified light sources which occur in both sets of data have accordingly been transformed from one system to the other by the equations quoted.

Taking for illustration the tungsten lamp at 1.25 w. p. c., this was found, through the trichromatic measurements, to have Koenig sensation values:

$$R = .479$$
$$G = .411$$
$$B = .110$$

These were transformed to the revised Koenig values by the relation 13, giving

$$R = .502$$
$$G = .393$$
$$B = .105$$

The spectrum hue from the color triangle is 0.586μ. The color triangle coefficients of this wave-length are

$$u = .570$$
$$v = .415$$
$$w = .015$$

From relations 9 and 10 we obtain

$$L'_C = .459$$
$$L'_W = .103$$
$$\frac{L'_W}{L'_C} = .224$$

(We note that in the case of measurements of illuminants we obtain only the *relative* values of the three colors mixed or the *ratio* of the color and white constituent luminosities, represented as before, by primed letters.) The corresponding values for the tungsten lamp as obtained by Jones's monochromatic measurements are

$$\text{hue} = .588\mu$$
$$\frac{L'_W}{L'_C} = .35$$

Now, taking Jones's monochromatic readings and applying relation 11, we obtain relative values for the three sensations, which when reduced to the same summed value as those obtained by the other method are

$$R = .472$$
$$G = .371$$
$$B = .157$$

This comparison was made upon several of the tabulated illuminants, with the result that the hue, as derived from the trichromatic measurements, was always quite close to the directly measured values, but the luminosity values were considerably different. Upon obtaining the sensation values from the monochromatic measurements and plotting them in the same color triangle with the trichromatic measurements, the transformed monochromatic ones were found to be *uniformly shifted toward the blue corner of the triangle.*

These differences between the two sets of measurements when reduced to the same terms find a possible explanation in a difference between the whites to which the measurements were referred. If, for example, Jones's measurements are expressed in terms of a point removed from the centre of the triangle a short distance toward the blue (that is, are referred to a bluer "white"), the greater part of the differences in the sensation values disappear. His values lie, in fact, between those the writer obtained[4] in an investigation using an average daylight as determined by Nichols, which is probably too yellow for a true average, and the values based on the 5000° black body, which has been thought to represent clear noon sunlight, or "average daylight" satisfactorily.

Obviously a complete test of these equations of transformation can be made only by comparing measurements by the two methods which have been made in terms of the same white. Assuming the essential correctness of the equations and the constants employed and the substantial similarity of the color vision of the two observers, the differences between the two sets of data under comparison form a valid indication of the different whites employed in the two cases. On the other hand, some recently published comparisons of spectrophotometric values, at three points in the spectrum, with three-color mixture values, obtained in another country, do not without elaborate transformations furnish any such information.[6]

GENERAL REMARKS ON COLOR MEASUREMENT.

In this paper have been gathered together or developed those data necessary for the transformation of three-color mixture measurements from one set of primaries to another, and for the transformation of hue, luminosity, and saturation measurements to three-color units, and *vice versa*. The fundamental color sensations have been emphasized as the units in which all color measurements should be expressed. The experimental values obtained by Koenig for these sensations (as distributed in the spectrum) have been used to form slightly modified values, which are now available for the numerical description of color in the simplest possible terms.

It is the writer's hope that this work will help to clear up some obscure points and misunderstandings on the subject of color measurement, and so bring the problem nearer to satisfactory solution. It is well, however, to point out that color measurement is simpler in theory than in practice, for a number of reasons. We have, first and foremost, to contend with the difference in color vision between different observers. Anything except an exact spectral match, wave-length by wave-length, fails to be an integral color match with individuals of different color vision. Both the practical methods of color measurement suffer from this limitation, since they both provide merely subjective matches. This difficulty can be met only by the careful selection of a group of observers who shall meet some vision test, as yet unspecified. But even with this precaution there are serious difficulties, prominent among which is the fact that the technical requirements for precision are altogether too severe for any present optical instrument to meet. The comparison of juxtaposed surfaces without the intervention of any instrument represents the condition under which the eye is at its maximum sensibility for the discrimination of small color differences. Colors which will measure up alike by instrumental means (which themselves are dependent on the eye) will frequently fail by the test of simple side-by-side comparison.

A difficulty standing in the way of the practical use of some of the transformations dealt with here is the lack of a standard artificial reproducible white light—a deficiency which may be met by the adoption of an instrument recently constructed for the spectroscopic synthesis of colors.[7] The difficulties in the way of measuring colored light luminosities have been hinted at. The most promising means of meeting them appears to the writer to be the development of physical photometers which shall incorporate the characteristics of the average eye. The measurement and specification of color may also find its ultimate practical solution in the development of a sensitive physical artificial eye, such as that recently described by the writer.[8] Where great accuracy is necessary, however, it is very questionable whether either of the three element methods of analysis will ever be satisfactory, beautifully simple though they are in theory.

A spectrophotometric table, derived from at least 25 points (for a continuous spectrum), gives the only unique description of a color, and it appears probable to the writer that the requirements of precision technical color measurement are most likely to be met by the development of simple and rapid means of plotting and recording accurate spectrum plots of reflection or transmission characteristics. But for descriptive purposes, where great accuracy is not imperative, the three-element systems are excellent when properly used.

Physical Laboratory, United Gas Improvement Company,
Philadelphia, July 23, 1915.

REFERENCES.

[1] Abney: Various papers in *Trans. Royal Society*, 1880–1915.

[2] Koenig: "Gesammelte Abhandlungen zur Physiologischen Optik," Leipzig, J. A. Barth, 1903.

[3] Ives: "The Ives Colorimeter in Illuminating Engineering," *Trans. Ill. Eng. Soc.*, Nov., 1908, p. 627.

Ives: "Color Measurements of Illuminants, a Résumé," *Trans. Ill. Eng. Soc.*, April, 1909, p. 189.

Ives: "The Relation between the Color of the Illuminant and the Color of the Illuminated Object," *Trans. Ill. Eng. Soc.*, Feb., 1912, p. 62.

[4] Abney, *loc. cit.*

Ives: "The Daylight Efficiency of Artificial Illuminants," *Bull. Bureau of Standards*, vol. 6, No. 2, p. 231.

Nutting: "A Precision Colorimeter," *Bull. Bur. of Standards*, vol. 9, No. 1, p. 1.

Jones: "The Color of Illuminants," *Trans. Ill. Eng. Soc.*, vol ix, No 8, 1914, p. 687.

Ives: Discussion of paper by Jones, *Trans. Ill. Eng. Soc.*, vol. 9. No. 1, p. 702.

[5] Ives and Kingsbury: "Physical Photometry with a Thermopile Artificial Eye," *Physical Review*, Nov., 1915, p. 319.

[6] Jasse: "Über die graphische Darstellung farbiger Lightquellen," *Electrotechnische Zeit.*, Dec. 18, 1913, p. 1454.

[7] Ives and Brady: "An Apparatus for the Spectroscopic Synthesis of Color," JOURNAL OF THE FRANKLIN INSTITUTE, July, 1914, p. 89.

[8] Ives: "A Precision Artificial Eye," *Physical Review*, Nov., 1915, p. 334.

Printing Three Colors at One Impression. ANON. (*The Engraver and Electrotyper*, October, 1915.)—A machine to print the three primary colors at one impression, which may effect a considerable saving in the cost of printing, though not in the cost of the plates, has been invented by T. R. Johnston, of Japan. According to the inventor, this machine will produce prints in three colors on small sheets in less time than the machines in general use will print one color on large sheets.

On the form bed are placed, side by side, the three blocks or chases for the yellow, red, and blue printings. The ink duct is divided so as to supply these colors to different portions of the inking rollers which respectively cover their blocks. The press can be either the stop-cylinder or the two-revolution type.

There are three sheets on the cylinder at one time: the first, receiving its yellow impression; the second, having already had its yellow impression, receiving its red impression; and the third, having already had its yellow and red impressions, receiving its blue impression.

A sheet being fed to the cylinder grippers first receives its yellow impression, and then when the cylinder is stationary, as it will be if of the stop-cylinder type, or when it is making its second revolution, if of the two-revolution type, the sheet moves along the cylinder's surface so that at the cylinder's next revolution it receives a second impression from the red block. After receiving this impression it again moves along the cylinder's surface and receives its blue impression, after which it is removed to the delivery apparatus. Consequently at every revolution of the cylinder a sheet is produced in three colors.

By this invention, once a sheet is taken by the cylinder grippers it is retained by them until the printing is completed and correct register is therefore insured. With the exception of the printing blocks, nothing touches the faces of the sheets from the time they are fed in until they are delivered face upwards.

There are several advantages in this method of printing, one being that, as the colors are printed immediately after each other, there is not time for the atmosphere to act on the paper and alter its size, this alteration causing a great deal of trouble in the securing of register when one color is printed at a time and an interval elapses before another color is applied to the sheets. Another advantage is that the inking and distributing rollers and ink duct have to be cleaned only once for all three colors.

Aërodynamical Experiments upon a Yacht's Mainsail. H. A. EVERETT. (*Proceedings Society of Naval Architects and Marine Engineers*, November 18 and 19, 1915.)—Primarily designed for the investigation of problems in aërial navigation, the aërodynamical laboratory is proving of value in the older art of the design of ships' sails. By means of the " wind tunnel " of the Aëronautical Laboratory of the Massachusetts Institute of Technology experiments have been made upon a model sail to determine the true centre of pressure, the normal pressure per unit of area for a given wind velocity, and the proper angle of boom to centre line for fastest sailing over a given course. The " wind tunnel " consists essentially of a square duct, 4 feet on a side, through which a current of air is drawn at uniform velocity with a balance under it which supports the models to be tested and weighs the forces acting on them.

The experiments were carried out with a model of the mainsail of a racing yacht made to a scale of 3/8 inch to 1 foot. Among the other results of the experiments it was shown that for courses from 45° to 160° with the apparent wind (shown by the fly at the masthead) the angle between the boom and the centre line of the ship for best sailing with this sail should be approximately one-half the angle between the fly at the masthead and the centre line of the ship.

ON THE BOILING-POINT OF AQUEOUS SOLUTIONS OF NITRIC ACID AT DIFFERENT PRESSURES. PART II.—THE INFLUENCE OF WATER-RETAINING AGENTS ON THE COMPOSITION OF THE MIXTURE OF MAXIMUM BOILING-POINT.*

BY

HENRY JERMAIN MAUDE CREIGHTON,
Member of the Institute,

AND

HERSCHEL GASTON SMITH,
Department of Chemistry, Swarthmore College.

In a previous investigation[1] it was found that the composition of the mixture of maximum boiling-point formed by nitric acid and water changes but slightly with pressure, varying from 66.80 per cent. of nitric acid at 110 mm. pressure to 68.18 per cent. of acid at 760 mm. pressure. These results indicate that the content of nitric acid in the mixture of maximum boiling-point increases slowly as the pressure is raised. It was hoped to continue the investigation at higher pressures, but, since preliminary experiments indicated that at high pressures the nitric acid undergoes considerable decomposition when its aqueous solutions are heated to their boiling-points, it was deemed advisable first to study the influence of the presence of certain non-volatile water-retaining agents on the composition of the mixture of maximum boiling-point.

In the following experiments sulphuric acid and anhydrous potassium acid sulphate have been employed as water-retaining agents.

The apparatus, procedure, and precautions employed in this investigation are essentially the same as those recorded in Part I. Further precautions have been used to prevent a temporary cooling of the bulb of the thermometer by liquid condensing on its sides. This has been accomplished by catching the descending liquid some distance above the bulb of the thermometer, and leading it away to the inside of the thin-walled tube surrounding the thermometer. In order to achieve this, a piece of glass tubing about 2 cm. long, with an internal diameter about 2 mm. greater than the diameter of the thermometer, was placed around the latter at a distance of 70 mm. above the bulb, and the space between the glass ring and the thermometer was packed with asbestos. The upper edge of the ring was slightly bevelled so as to permit easy packing with the asbestos, and at the bottom two flutes, or spouts, were made to carry off the liquid which passed down through the asbestos. The ring was held in position by wrapping a piece of platinum wire around the thermometer below the lower edge of the ring. Two views of the ring and thermometer are shown in Fig. 1. The arrangement just described was found to be very effective and entirely prevented any cooling of the thermometer by the condensed liquid.

---

* Communicated by Professor Creighton.

[1] Creighton, H. J. M., and J. H. Githens, Journal of The Franklin Institute, 179, 161 (1915).

From the values obtained at atmospheric pressure the boiling-points at 760 mm. were calculated.[2] In all determinations of the boiling-point the thermometer readings were corrected for the cooling of the mercury thread which extended above the neck of the flask in which the liquid was boiled.[3] The aqueous solutions of nitric acid were heated to boiling, and, after the boiling-point became constant, the liquid remaining in the flask was quickly cooled and its content of nitric acid determined with standard barium hydroxide, phenolphthalein being used as indicator.

Determinations of the boiling-points of aqueous mixtures of nitric acid have been carried out, at 760 mm. pressure, in the presence of 10 and 20 per cent. of anhydrous potassium acid sulphate; and at 760, 360, and 200 mm. pressure, in the presence of 10 and 20 per cent. sulphuric acid. The results of these determinations are recorded in Tables I, II, and III. The percentages of nitric acid given in these tables refer to a dehydrating-agent-free solution, the weight of the dehydrating agent having been deducted in calculating the nitric acid content. Isobaric curves showing the change in the boiling-point with variation in the composition of the mixture are shown in Fig. 2 and Fig. 3. For the purpose of comparison, curves showing

---

[2] Kahlbaum, G. W. A., *Ber.*, 19, 3101 (1886).

[3] Rimbach, E., *Ber.*, 22, 3072 (1889).

FIG. 1.

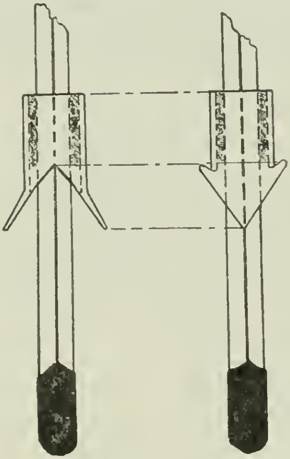
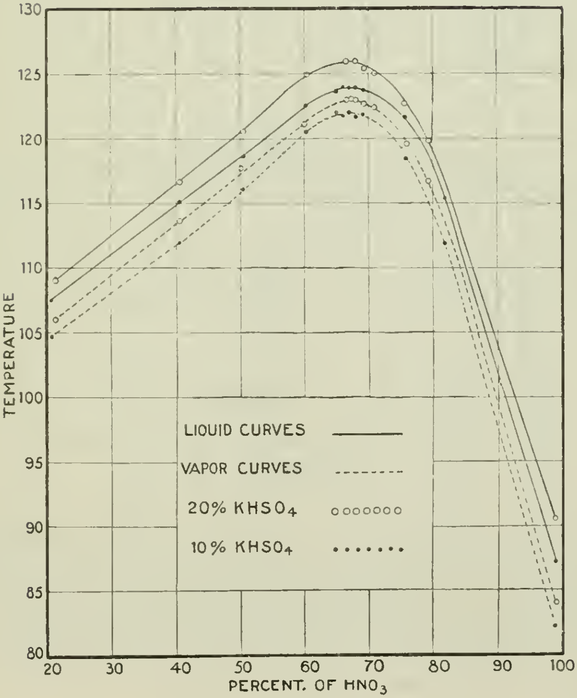
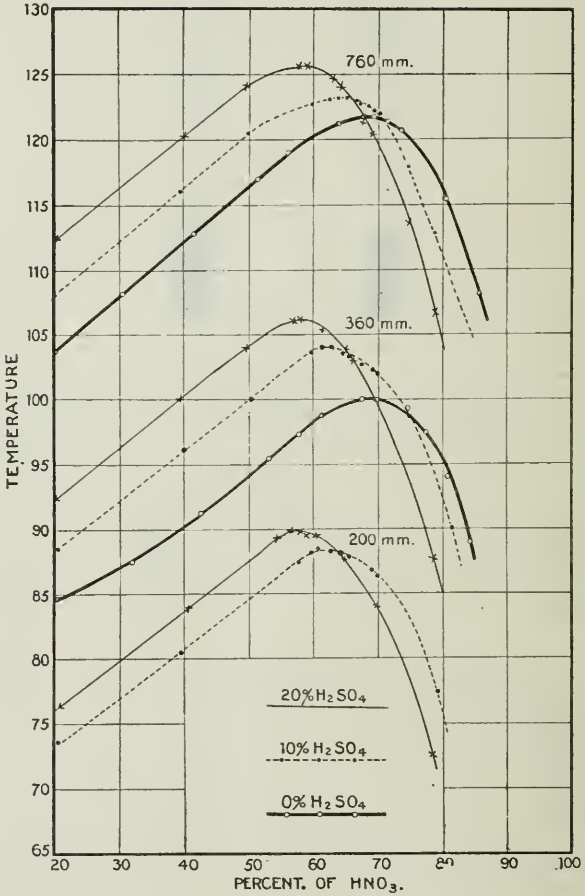


FIG. 2.


130
125
120
115
110
105
100
95
90
85
80
TEMPERATURE
20
30
40
50
60
70
80
90
100
PERCENT. OF HNO_3
LIQUID CURVES
VAPOR CURVES
20% $KHSO_4$ ○○○○○○○
10% $KHSO_4$ •••••••

the change in the boiling-point of pure, aqueous solutions of nitric acid at 760 and 360 mm. pressure are given in Fig. 3. These latter curves have been constructed from data previously obtained.[4]

Fig. 3.



It will be seen that the curves in Fig. 2, which represent the change in the boiling-point of the liquid and in the temperature of the vapor that is in equilibrium with the boiling liquid, with variation in composition, are fairly parallel, and that their shape is characteristic of a mixture of maximum boiling-point. Furthermore, it will be observed that little or no displacement of the maxima of the curves occurs, indicating that the composition of the mixture of maximum boiling-point remains constant with increase in the amount of potassium acid sulphate present.

---

[4] Creighton, H. J. M., and J. H. Githens, *loc. cit.*

TABLE I.

PRESSURE=760 mm.

Boiling-point of Aqueous Mixtures of HNO_3 in the Presence of:

10 per cent. $KHSO_4$			20 per cent. $KHSO_4$		
Per cent. HNO_3	Temperature of:		Per cent. HNO_3	Temperature of:	
	Liquid, degrees	Vapor, degrees		Liquid, degrees	Vapor, degrees
20.5	107.5	104.8	21.1	109.1	106.1
40.4	115.0	111.9	40.4	116.6	113.6
50.3	118.6	116.1	50.2	120.6	117.8
60.3	122.5	120.5	60.4	124.9	121.1
65.0	123.6	122.1	65.2	126.0	122.7
66.0	123.9	121.7	66.4	126.0	123.1
67.0	124.0	122.0	67.1	126.1	123.4
68.2	124.0	121 6	68.0	126.0	123.2
69.3	123.7	121.8	69.3	125.5	122.7
....	.....	.....	70.8	124.9	122.5
75.7	121.7	118.5	75.4	122.7	119.6
81.7	115.3	111.7	79.3	119.8	116.8
99.0	87.2	82.2	99.1	90.6	84.1

TABLE II.

Boiling-point of Aqueous Mixtures of HNO_3 in the Presence of 10 Per Cent. H_2SO_4.

Pressure = 760 mm.			Pressure = 360 mm.			Pressure = 200 mm.		
Per cent. HNO_3	Temperature of:		Per cent. HNO_3	Temperature of:		Per cent. HNO_3	Temperature of:	
	Liquid, degrees	Vapor, degrees		Liquid, degrees	Vapor, degrees		Liquid, degrees	Vapor, degrees
20.2	108.0	105.8	20.5	88.5	86.2	20.5	73.5	71.5
39.6	116.0	114.2	39.8	96.0	94.4	39.6	80.4	79.4
49.7	120.5	118.4	50.3	100.0	98.3	57.5	87.5	85.9
59.7	122.6	121.1	59.5	103.6	102.0	59.5	88.2	86.7
62.6	123.1	122.4	61.0	104.2	102.5	60.5	88.6	87.1
63.8	123.2	122.6	62.7	103.9	102.2	62.7	88.3	86.9
65.1	123.2	122.5	64.4	103.4	102.1	64.3	88.2	86.6
66.7	123.0	122.4	65.2	103.3	102.0	65.3	87.8	86.2
67.2	122.8	121.9	67.3	102.7	101.5	66.9	87.5	85.8
68.5	122.6	120.9	....	.....	.....	....	....	....
69.1	122.1	120.5	69.0	102.2	101.0	69.2	87.0	85.5
70.2	122.1	120.6	69.7	101.9	100.4	69.7	86.5	85.1
74.4	117.8	116.6	74.7	98.8	97.0	....	....	....
78.8	112.8	110.2	81.3	90.1	87.3	79.3	77.5	74.4
97.7	85.7	83.7	....	.....	.....	....	.....	....

TABLE III.

Boiling-point of Aqueous Mixtures of HNO_3 in the Presence of 20 Per Cent. H_2SO_4.

Pressure = 760 mm.			Pressure = 360 mm.			Pressure = 200 mm.		
Per cent. HNO_3	Temperature of:		Per cent. HNO_3	Temperature of:		Per cent. HNO_3	Temperature of:	
	Liquid, degrees	Vapor, degrees		Liquid, degrees	Vapor, degrees		Liquid, degrees	Vapor, degrees
20.1	112.2	109.3	19.9	92.2	88.7	20.5	76.3	74.4
40.2	120.1	117.4	39.6	100.3	97.8	40.4	84.1	81.8
49.5	124.3	122.5	49.7	103.8	101.3	54.2	89.3	86.7
57.8	125.4	123.1	56.8	105.8	103.3	56.5	89.9	86.7
59.2	125.6	123.6	58.2	106.2	103.0	57.9	89.9	86.8
61.8	124.3	123.3	59.3	105.3	103.3	58.8	89.5	86.5
62.7	124.1	122.6	60.9	105.1	102.9	60.6	89.5	86.4
64.1	123.9	121.9	64.4	103.7	100.5	62.7	88.6	86.3
67.5	121.3	118.8	65.7	102.9	99.2	64.5	87.7	85.3
69.1	120.4	117.8	69.5	100.2	96.1	69.5	84.2	80.8
74.8	113.4	109.5	....	.....	.....	....	....	....
78.8	106.8	101.0	78.4	87.7	82.8	78.4	72.6	67.0
97.1	87.9	83.9	98.6	68.7	65.5	....	....	....

The curves in Fig. 3, which represent the change in the boiling-point of aqueous solutions of nitric acid, in the presence of different amounts of sulphuric acid, with variation in composition, are also fairly parallel, and their shape is characteristic of a mixture of maximum boiling-point. Examination of these curves shows that, for a given pressure, the boiling-point is increased and the position of the maxima is appreciably displaced in the direction associated with a decrease in the nitric acid content of the mixture of maximum boiling-point, as the amount of sulphuric acid present is increased. At 760 mm. pressure the position of the maxima corresponds to the following amounts of nitric acid in the mixture of maximum boiling-point: 68.18 per cent. when no sulphuric acid is present, 64.5 per cent. in the presence of 10 per cent. sulphuric acid, and 59.2 per cent. in the presence of 20 per cent. sulphuric acid. It will further be observed that the position of the maxima is displaced slightly towards the left as the pressure is decreased.

The results of this investigation show that, although the boiling-point of the mixture of maximum boiling-point is raised by the presence of additions of potassium acid sulphate, the elevation of the boiling-point is not attended with any appreciable change in the composition of the mixture of maximum boiling-point. On the other hand, additions of sulphuric acid to aqueous solutions of nitric bring about a material change in the composition of the mixture of the maximum boiling-point, and these changes are further slightly increased as the pressure at which boiling takes place is lowered. These results show clearly why 68 to 69 per cent. aqueous solutions of nitric acid (mixture of maximum boiling-point) can be concentrated to over 90 per cent. by distillation with concentrated sulphuric acid; and they indicate that still better results would be obtained if the distillation were carried out at diminished pressure. On the other hand, potassium acid sulphate would be of little or no use in concentrating aqueous solutions of nitric acid.

SUMMARY.

1. The influence of the presence of potassium acid sulphate and sulphuric acid on the boiling-points of aqueous solutions of nitric acid has been studied at atmospheric and diminished pressures.
2. It has been found that, while the presence of potassium acid sulphate brings about little or no change in the composition of the mixture of maximum boiling-point, additions of sulphuric acid to aqueous solutions of nitric acid cause a decrease in the nitric acid content of the mixture of maximum boiling-point, the decrease being greater the greater the addition of sulphuric acid.
3. Diminishing the pressure has also been found to cause a slight further decrease in the nitric acid content of the mixture of maximum boiling-point.
4. The results obtained show clearly why aqueous solutions of nitric acid can be concentrated to over 90 per cent. by distillation with concentrated sulphuric acid.

Chemical Laboratory, Swarthmore College,
Swarthmore, Pa., October 25, 1915.

Variation of Frictional Resistance of Ships with Condition of Wetted Surface. W. McEntee. (*Proceedings Society of Naval Architects and Marine Engineers,* November 18 and 19, 1915.)—Considering that frictional resistance is the most important element in the resistance of practically all ships, it is noteworthy that investigations of conditions affecting it have been relatively few. At various times attempts have been made to reduce the frictional resistance of ships by lubricating the under-water surface or by polishing to a high degree with various materials. One favored method used for racing yachts is to polish the bottom with black lead or graphite.

An investigation of the benefits to be expected from such polishing or lubrication has recently been made at the Model Basin of the United States Navy with friction planes. These planes are of wood, roughly 20 feet by 2 feet by 3/4 inch, with ends sloped forward at an angle of about 30 degrees. The total wetted surface for each is about 82 square feet.

Trials were made with planes coated with shellac, black lead, ivory soap, heavy cylinder oil, and light cylinder oil. The results of the experiments indicate that no advantage over a smooth varnish on shellacked surface is obtained with the materials used. For each lubricating surface the resistance is greater than for the shellacked surface. The resistance increases in the following order: black lead, light engine oil, ivory soap, heavy cylinder oil. The black lead, although yielding a result nearly as low as the shellac, is easily rubbed off when the surface is wetted.

Solving the Potash Problem. ANON. (*United States Commerce Reports,* No. 25, October 28, 1915.)—Several new methods of increasing the supply of American potash have recently been brought to the attention of the Bureau of Foreign and Domestic Commerce. One of the most promising of these efforts to find a substitute for German fertilizers is a patent taken out a few weeks ago by a Canadian for a method of using the potash in ordinary feldspar.

The process is a simple one, consisting of heating the feldspar with limestone and iron oxide at a temperature of about 2200° F., which produces a partly-fused mass that is easily decomposed by a weak acid. From this product the potash salts can readily be extracted for further purification. The inventor has been in consultation with Dr. Norton, the expert, who has been looking after the potash and dyestuff situations for the Bureau of Foreign and Domestic Commerce, and it seems very possible that a greatly-simplified method of transforming feldspar into fertilizer will soon be available.

A practical try-out for another method of obtaining potash fertilizer will soon take place at a New Orleans distillery where molasses is used in large quantities. It is a fact that 106 tons of potash are wasted daily by the 25 or more distilleries in this country that subject molasses to processes of fermentation. The New Orleans company is planning to install the process of saving the potash in distillery waste recently brought to the attention of the public by the Bureau of Foreign and Domestic Commerce. It should be possible to make fertilizer from this otherwise worthless material at a price that will meet competition even after the war is over.

THE PRODUCTION OF LIGHT BY ANIMALS*.

BY

ULRIC DAHLGREN,

Professor of Biology, Princeton University.

Several groups of unicellular organisms other than the bacteria are capable of luminosity. There are the *Dinoflagellata* and the *Cystoflagellata* of the class *Flagellata* or *Mastigophera* of Protozoa, also the *Radiolaria* of the class *Sarcodina*.

When we look over the large phylum of the protozoa as classified by the various authorities, and scan the lists of luminous forms so far known, we are struck by the fact that only those that are found in salt water are light producers. Furthermore, these light producers are almost limited to strictly pelagic forms that live on the surface of the sea and are known as plankton forms.

The forms that can produce light are homogeneous pelagic groups whose members appear to be highly specialized and to have had their origin as well as passed their phylogenetic history on the surface of the sea. They have, apparently, been thus continuously influenced by the unknown factors of this pelagic life that results in the specialization of the light-producing power in so many other organisms that have this same habitat. The Radiolarians and Cystoflagellates are such kinds of protozoa.

Not all plankton protozoa, however, can produce light. We find a number of kinds in which the power is not developed, although they are found in the marine plankton. Some of these are, evidently, recently adapted to the life and come from groups that are principally found in the fresh waters of the earth. Perhaps in this case they have not existed in salt water long enough to have developed the power. Other pelagic forms appear to have no luminous members, although they are largely found in salt water, and from their numbers and variety seem to have originated there.

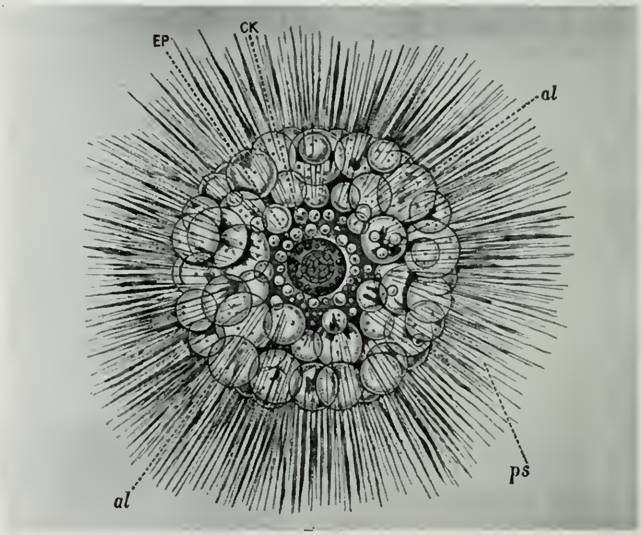
The Radiolarians are a group of protozoa in which the light-producing power has been well observed, especially in the colonial forms and also in the simpler or single-celled forms.

---

* Continued from page 537, November issue.

As far back as 1803, Tilesius mentioned the luminosity of a species of Radiolarian, probably the common form Thalassicola found in the Mediterranean Sea (Fig. 1). Others who mentioned Radiolarians as light-giving were W. Baird, Meyen, Giglioli, Meyer, and MacDonald. Brandt, in his monograph on the colonial Radiolarians in the "Flora und Fauna des Golfes von Neapels," first made careful experiments and observations on these forms and proved that they had the power to produce light. He studied especially the colonial forms, of which *Collozoum inerme* is a good example (Fig. 2).

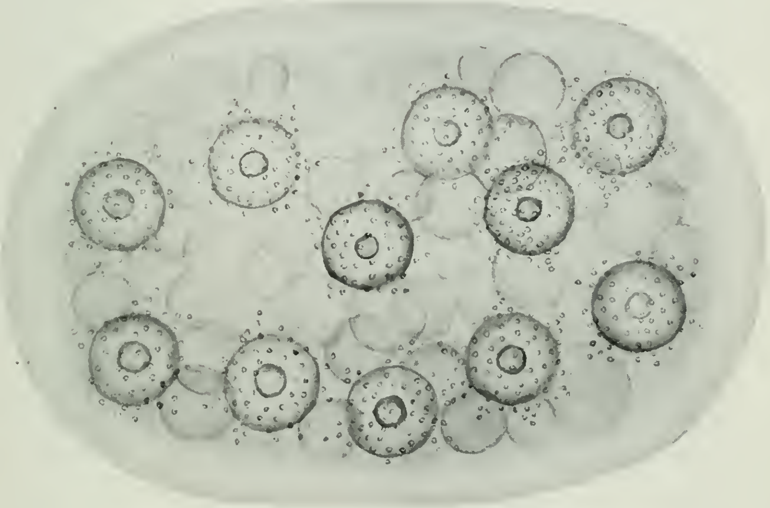
FIG. 1.



Thalassicola (*Thalassophysa*) *pelagica*, Haeckel. × 25. *CK*, central capsule; *EP*, extracapsular protoplasm; *al*, alveoli, carbonic acid-holding vacuoles in the mucilaginous calymma secreted by the protoplasmic network; *ps*, pseudopodia. The minute unlettered dots are the "yellow cells." (After Lankester.)

He filtered a quantity of fresh sea-water into a glass vessel so as to exclude all other organisms that might possibly be present, and carefully placed about twenty living specimens of *Myxosphæra cœrulea* in this water, which was then placed in a quiet, dark room at about the temperature of the sea. After allowing the experiment to rest for several hours he observed that no light was given off by it. He then moved the water in the glass gently, and the mechanical stimulation caused the organisms to show a weak light. When the water was shaken somewhat more violently the *Myxosphæra* as well as *Collozoum* and other forms glowed brightly as little balls of light with a perceptible aurea (Fig. 3). The exact color of this light was not mentioned. The observer then turned on artificial lights in the room and made sure that the balls of light were in reality the animals he had put into the water, and that no other creatures were present —an important measure in identifying any organism as the source of a light.

FIG. 2.

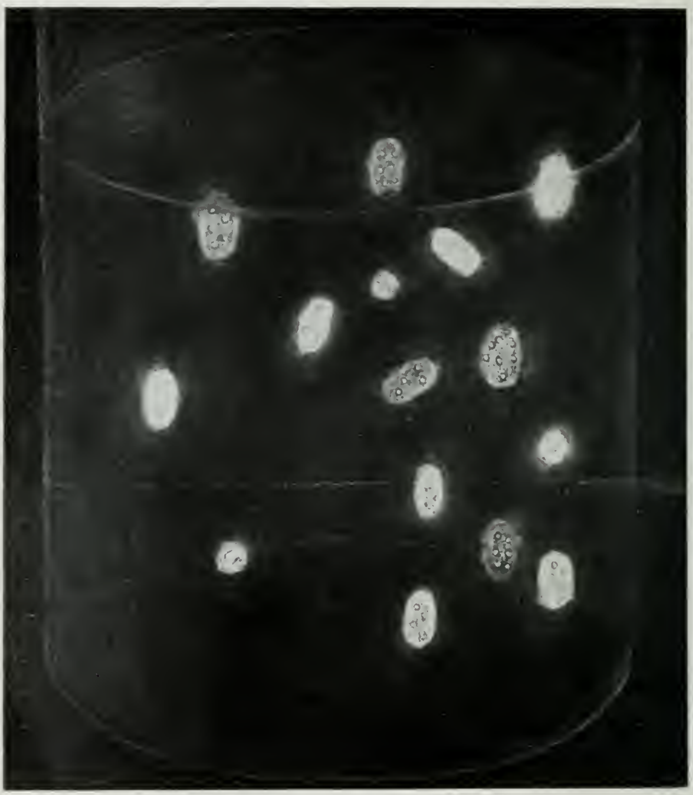


General view of a colonial radiolarian, *Collozoum inerme*, as seen under the microscope by transmitted light. It consists of a mass of jelly in which are numerous rounded spaces or vacuoles. Among these vacuoles are seen twelve "nests" or individual colonies, each with a large, round oil droplet in its centre. Around each "nest" are the swarm of the "yellow cells" or symbiotic algæ that live in the radiolarian. Nuclei, etc., are not seen in this figure. To understand the cell structure of these colonies see Fig. 4. (After Brandt.)

Several other interesting observations were made. When the animals had been made to light for some time by such mechanical stimulation it was found that they became incapable of further luminosity, and that the light died out entirely. This fact was taken to mean that they had used up some material that must be secreted and stored before being used to produce light; for all other conditions remained the same, especially the supply of free O_2 in the sea-water necessary for light production.

In order to confirm this conclusion the experimenter allowed the animals to rest quietly in this sea-water for from one to two hours. During this time they remained dark, but at the end of the period, when shaken again, they glowed a second time, which was taken to show that they had secreted a new supply of the material during their rest.

FIG. 3.



Drawing representing six adult colonies of *Collozoum inerme*, to show their appearance when shining in the dark as described by Brandt for *Myxosphæra cœrula*, *Collozoum inerme*, and other forms of colonial radiolarians. The light emanates from the region around the oil globule in each colony, giving each colony its own marked halo and the entire colony a halo that makes it appear as a ball of weak light. (Original drawing by E. Grace White after Brandt's description.)

Another experiment with the same animals was then tried. Fresh water was thrown on them, and the resulting light was even brighter than when they were shaken. Also when ammonia was

Name	ochemical features								
	Gas production			Reaction of broth +	Nitrates reduced	Indol produced	Optimum temperature above 22°	Grows in milk	Pathogenic
	broth	Lactose broth	Saccharose broth						
Bacillus Pflugeri group:									
Bacillus annularis Fischer									
Bacillus coronatus Fischer	+	–	+					+	
Bacillus degeherins Fischer									
Bacillus Fischeri Bey	–	–	–		+		–		
Bacillus hirsutus Fischer							–		+c
Bacillus pflugeri Lud							–		+c
Bacillus phosphorescens Fischer							–		
Bacillus tuberosus Fischer									
Bacillus from meat, Gorham									
Bacillus indicum Fischer	–	–	–				+	–	+
Bacillus balticus Bey							–		
Bacillus phosphoricus Mig							–		
Bacillus argenteo-phosphorescens Mig									
Bacillus plymouthii									
Microspira luminosa group:									
Microspira caraibica Fischer							+		+
Microspira glutinosa Fischer									
Microspira javaneasis Eij	–	–	–				+	–	
Microspira luminosa Bey							+	–	
Microspira dunbari Mig	–	–	–			+		+	+
Microspira from sea-water, Gorham	–	–	–					–	

hese
when
when
ation
wing
n of
ty of
e of

th of
nical
erine
ably
r for

ians,
leyi,
and
not
was
ls of
l not
va-

with
e de-
nion

Fig.
Here
ss of
bers
4)
ch is
as it
nd a
the
t of
plet.

Name	Source	Morphology									Cultural features										Biochemical features												
											Broth tubes			Agar tube		Gelatin stab			Potato				Liquefaction			Gas production							
		Bacillus	Spirillum	United in chains	Motile	Flagella	Spores	Capsules	Stains easily	Stains by Gram's	Turbidity	Pellicle	Sediment	Dull	Wrinkled	Deep funnel	Surface growth	Needle Growth	Visible	Luxuriant	Grows at 37.5°	Facultative anærobic	Gelatin	Casein	Blood serum	Dextrose broth	Lactose broth	Saccharose broth	Reaction of broth ±	Nitrates reduced	Indol produced	Optimum temperature above 22°	Grows in milk	Pathogenic
lus Pflugeri group:																																		
Bacillus annularis Fischer	Sea-water	+	−	−	+	+	−			−	+	+	+	−	−				−	−			+s											
Bacillus coronatus Fischer	Sea-water	+	−	−	+	+	−		−	−	+	−	+	−	−	+	+	+	−	−	+	+	+s	−		+	−	+					+	
cillus degeberins Fischer	Sea-water	+	−	−	+	+	−		−	−	+		+	−	−		+	+	−	−	−		+											
acillus Fischeri Bey	Sea-water	+	−	−	+	+	−			−	+	+	+	−	−				−	−	−	+	+s			−	−	−		+		−		
acillus hirsutus Fischer	Fish and sea-water	+	−	−	+	+	−		+	−	+	+	+	−	−		+	+	−	−			+s									−		+c
acillus pflugeri Lud	Fish	+	−	−	+	+	−			−				−	−	−	+	−	−	−	−		−									−		+c
Bacillus phosphorescens Fischer	Fish and sea-water	+	−	−	+	+	−			−	+	−		−	−		+	+	−	−	−		−									−		
llus tuberosus Fischer	Sea-water	+	−	−	+	+	−		+	−	+	+	+	−	−		+	+	−	−			+s											
Bacillus from meat, Gorham	Meat	+	−	−	+	+	−	+	−	−				−	−																			
Bacillus indicum Fischer	Sea-water	+	−	−	+	+	−		−	−	+	+	+	−	−	+	+	+					+	+		−	−	−				+	−	+
Bacillus halticus Bey	Sea-water	+	−	−	+	+	−		+	−	+	−		−	−						−		+									−		
Bacillus phosphoricus Mig	Fish and sea-water	+	−	−	+	+	−			−	+	+										+	−									−		
Bacillus argenteo-phosphorescens Mig	Fish and sea-water	+	−	−	+	+	−		+	−	+	−					+	+	−			−	+s											
llus plymouthii	Sea-water	+	−	−	+	+	−		+	−	+		+										+											
crospira luminosa group:																																		
Microspira caraibica Fischer	Sea-water	−	+	−	+	+	−		+	−	+	+	+	−	−		+	+			+	−	+									+		+
Microspira glutinosa Fischer	Sea-water	−	+	−	+	+	−		+	−				−	−								+											
icrospira javaneasis Eij	Fish	−	+	−	+	+	−		+	−	+	−	+	−	−	−	+	+			+		+s			−	−	−				+	−	
icrospira luminosa Bey	Fish and sea-water	−	+	−	+	+	−			−	+	+	+	−	−				−	−			+s									+	−	
Microspira dunbari Mig	Sea-water	−	+	−	+	+	−		+	−	−	+	−	−	−	+	+	+	+	−	+	+	+			−	−	−			+		+	+
Microspira from sea-water, Gorham	Fish and sea-water	−	+	−	+	+	−		−	−	+	+	+	−	−	−	+	+	+	+	+		+			−	−	−					−	

put in the water an even brighter light was produced. These two stimuli, of course, killed the protozoa in a few seconds, when the light was ended for all time. It was noticed that even when the light production was exhausted by mechanical stimulation still some more could be produced by chemical means, showing that an element of fatigue was present as well as an exhaustion of the luciferine. This fatigue may be interpreted as an inability of the organism to bring O_2 into contact with a small residue of luciferine.

In this connection it must be remembered that the strength of the luminosity is in proportion to the strength of the mechanical stimulus up to a certain point at which the supply of luciferine begins to diminish toward a vanishing point which is probably never reached. *Thalassicola nucleata* lighted in fresh water for fifteen to twenty minutes before dying.

Brandt also experimented with other forms of *Radiolarians*, as *Thalassicola nucleata, Collozoum inerme, Collosphæra huxleyi, Sphærozoum neapolitanum,* and *Sphærozoum punctatum*, and found that all of them reacted in a similar way. He did not study the physical characters of the light except to say that it was weaker than in other organisms, nor did he compare the kinds of light emitted by the different forms with each other. He did not study the influence of sunlight on the light production of the various forms.

Brandt also studied the structure of the *Radiolarians* with reference to any substance which might be the luciferine. He described the well-known " oil droplets," and gave it as his opinion that they were the seat of the luminosity.

In order to discuss this question the reader is referred to Fig. 2, which represents an adult colony of *Collozoum inerme.* Here it will be seen that the body of the organism or colony is a mass of jelly in which are imbedded a number (about 250) of the members or individuals of the colony. Each of these members (Fig. 4) consists of a round, multinucleated cell, in the centre of which is an oil droplet. The cytoplasm of this individual or " nest," as it is sometimes called, is divided into a larger central mass and a lesser outer zone which are separated from one another by the central capsule. The nuclei are placed in the peripheral part of the central mass, outside of and around the very large oil droplet.

Brandt denies Hertwig's idea that the oil droplet represents a storage of general food supply. He cites its enormous size and definite position as proof that it has some very special function. Also he quotes the work of Panceri and Radziszewisky to show that all luminous animals use a fat-like substance with which to produce light. Better than all, however, is his observation under the microscope that it is the extreme centre of each individual in a colony that lights. He states that this central point of light was rather large to be the oil droplet alone.

The facts of the case appear to the writer to be as follows: Recent studies have shown that luciferine is not a fat-like body soluble in alcohol, as this oil droplet appears to be. But, as described by Brandt himself, this body in the centre of the Radiolarian individual is not a homogeneous fat. It has an outer zone (Fig. 5) from which the fat can be squeezed, and this outer zone is not soluble in alcohol.

FIG. 4.

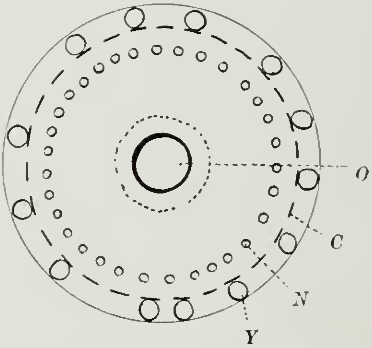


Diagram of a "nest" or individual colony of *Collozoum fulvorum*. *C*, central capsule; *O*, oil droplet; *N*, nuclei of the colony; *Y*, yellow cells (symbiotic algæ). (Modified after Brandt.)

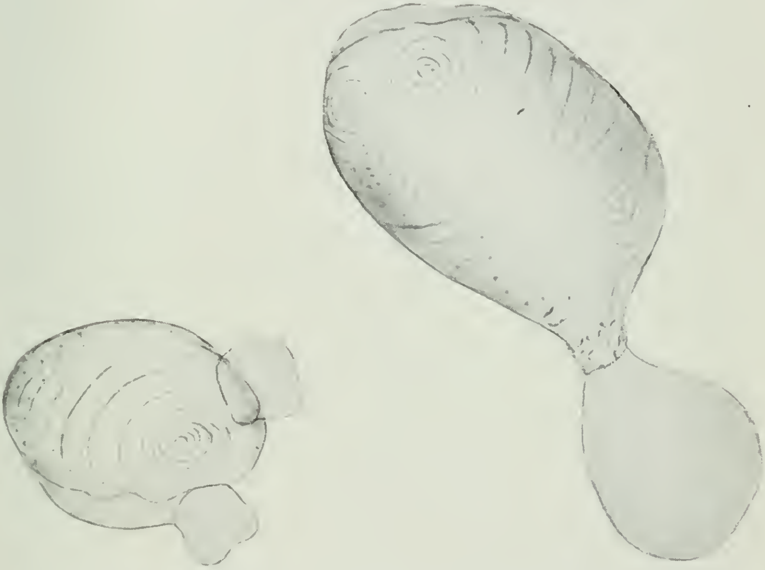
It is in this zone or in the shell of cytoplasm next to it that the light originates. Also it is probable that the materials for the secretion of luciferine are stored in the fat droplet and are withdrawn and elaborated by the nearby cytoplasm in which they rest until a stimulation causes them to be consumed in order to produce the light.

As to the use of the light or its biological meaning we have no clue. It possibly may serve as a warning signal. But it cannot be used to serve as an attraction or as a light by which the creatures can secure their prey, for the Radiolarians are quite motionless and cannot see. Also the light is a rather weak one.

Another group of protozoa, the *Peridiniaceæ*, as they are called by the botanists, or the *Dinoflagellata*, as the zoologists have named them, are also luminous.

These organisms are found all through the superficial seas of the world, and also in fewer numbers in fresh water. They are unicellular and are covered by a stout coat of cellulose, which is composed of two pieces, with more numerous plates, and is of various beautiful forms, according to the species. There is a constant groove present in all the forms, in which lie two stout, fleshy cilia or flagellæ that the animal uses to propel itself with. Chlorophyll and some red and brown pigments are present in some of the forms, although the pelagic forms are usually transparent. As typical of the group we will study the production of light in three forms, *Ceratium tripos*, *Peridinium bahamense*, and in an unidentified colonial form found in the lower parts

FIG. 5.

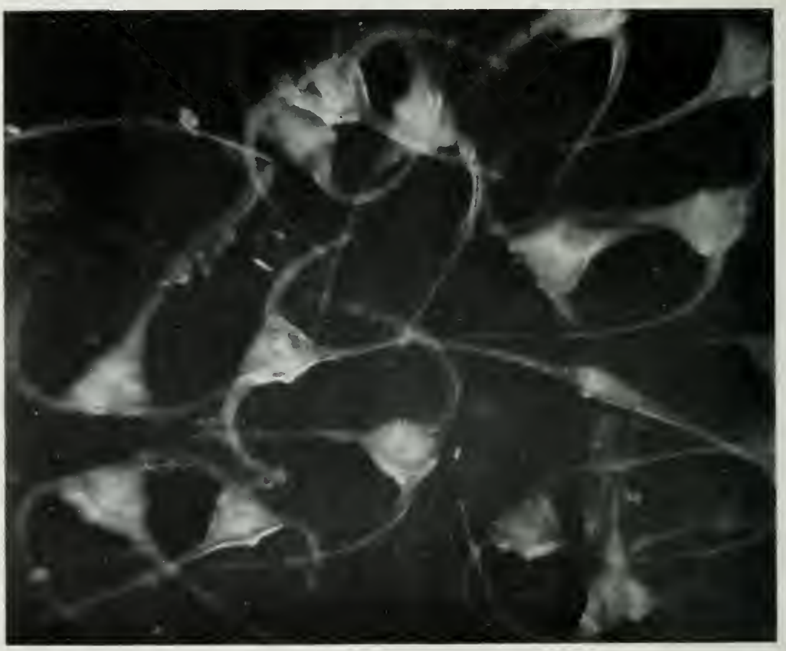


Two oil droplets from the centres of two individual colonies of *Sphærozoum neapolitanum*. These have been pressed under the cover-glass and show the oil-like material being pressed out in masses from the thick, soft covering. (After Brandt.)

of Delaware Bay and Chesapeake Bay, as well as other bays and sounds on the Atlantic coast of North America from New York to Florida.

Ceratium tripos was probably the first of these forms to be studied. It was thought that it produced light as distinct from *Noctiluca miliaris* as early as, or perhaps earlier than, 1811, when Tiedemann investigated it among the other marine "infusorians" that shone. Many other investigators and travellers mentioned light that probably came from some of the Dinoflagellates, but Ehrenberg was the first, in 1831, to look into the question in any adequate way. Later, some of the best work has appeared in monographs and papers by G. Schütt, Reinke, Gourret, Molisch, Zacharias, and others.

FIG. 6.



Photograph of living *Ceratium tripos* under a medium magnification. Dark stage illumination. × 125 diameters. (Original.)

Ceratium (Fig. 6) is found over most seas at the surface. While usually present or abundant, it is sometimes enormously

ova Scotia,
ool Bay, so
th as glass
vater. As
mark the
ong enough
loth, when
vith several
osed almost
tions were

determined
t. Molisch
ng in sea-
ope, and by
cohol, dis-
ght.

Germany,
when they
Thus they
l, mechani-
eidel spent
Harpswell,
surface at
ich. Their
e numerous
re light was
um was sil-
the resting
heir mutual
was drawn
l a brilliant
their bright

as roughly
he stimulus
It did not
n came the
et from the
n, although

Name	Synonyms	By whom found	Where	When	Authorities
Micrococcus phosphorescens, Cohn	M. Pflugeri, Ludwig ex parte M. Lucens, v. Fieghem Photob. phosphorescens, Bey. Bact. Lucens, Nuesch Arthra bact. Pflugeri, De Bary	Pfluger Cohn Ludwig Beyerinck Nuesch	Fish Meat	1874	Pfluger, '74. Cohn, '78. Nuesch, '77, '80. Schroter, '80. Ludwig, '87. Migula, 00, p. 78, Fig. Bd. I. T. a.
Bacillus Fischeri (Beyerinck), Mig.	B. phosphorescens indigenus, Kruse B. argenteo-phosphorescens (Katz), Mig. B. argenteo-phosphorescens I, Katz Einheimischer Leucht bacillus, Fischer Photob. Fischer, Bey. Microspira Fischeri (Bey.), Chester Vibrio Fischeri (Bey.), L and N.	Fischer Katz	Kiel Harbor Elizabeth Bay, N. S. Wales Baltic Sea	1888 1887	Fischer, '88. Beyerinck, '90. Katz, '91. Flugge, '96, p. 331. Migula, '00, p. 866, 869. Lehm. and Neum., '01, p. 371. Matzuschita, '02, p. 76, 298. Miquel and Cambier, '02, p. 881, 885
Bacillus Balticus (Fisch.), Bey.	B. phosphorescens Balticus, Matz. Photob. balticum (Fisch.), Bey. Vibrio balticus (Bey.), L. and N.	Fischer Beyerinck	Baltic Sea		Fischer. Lehm. and Nuem., '01, p. 371. Matzuschita, '02, p. 78. Barnard, '99, Figured.
Bacillus phosphorescens, Fischer	B. phosphorescens indicus, Kruse B. cyaneophosphorescens, Katz B. phosphorescens, Matz. Photob. indicum (Fisch.), Bey. Photob. cyaneum, Ludwig. Vibrio indicus (Bey.), L. and N.	Fischer Katz Beyerinck	Caribbean Sea Australian Ocean	1887 1887	Fischer, '89. Beyerinck, '90. Katz, '90. Flugge, '96, p. 330. Mace, '97, p. 933. Migula, '00, p 866. Lehm. and Nuem., '01, p. 370 Matzuschita, '02, p. 76, 68. Miquel and Cambier, '02, p. 882 Barnard, '99, Figure.
Bacillus phosphoricus, Mig.	B. argenteo-phosphorescens III, Katz.	Katz	Australian O. and Squid., Sydney	1887	Katz, '91. Migula, '00, p. 870. Matzuschita, '02, p. 98. Miquel and Cambier, '02, p. 882, 884.
Bacterium argenteo-phosphorescens (Katz), Mig.	B. argenteo-phosphorescens II, Katz B. argenteo-phosphorescens immobilis, Matz.	Katz	Australian Ocean Squid and fish, Sydney	1887	Katz, '91. Migula, '00. Matzuschita, '02, p. 374. Miquel and Cambier, '02, p. 882
Bacterium Giardi (Kruse), Mig.	B. phosphorescens Giardi, Kruse Photob. Giardi, Giard u. Billet. Photob. pathogenicum, Giard	Giard	Crustacea	1889	Giard, '89. Flugge, '96, p. 333. Matzuschita, '02, p. 374. Miquel and Cambier, '02, p. 883.
Bacterium liquefaciens plymouthii, Barnard	Photob. liquefaciens plymouthii, Barnard	Barnard	Polyzoa, Plymouth	1899	Barnard, '99, Figure.
Bacterium Pflugeri (Ludwig), Chester	Photobacterium Pflugeri, Ludwig B. phosphorescens gelidus, Forster B. phosphorescens Pflugeri, Kruse Bact. Lucens, Nüesch M. Pflugeri, Ludwig ex parte	Forster Pfluger Ludwig	Fish Fish, North Sea Meat	1874	Ludwig, '87. Forster, '87. Flugge, '96. Matzuschita, '02, p. 374. Miquel and Cambier '02, p. 885.
Bacterium phosphorescens, Fischer	B. smaragdino-phosphorescens, Katz Photob. phosphorescens, Bey. Photob. phosphorescens gelidus Bact. smaragdino-phosphorescens (Katz), Mig. Bact. smaragdinum (Katz), Chester Microspira phosphorescens (Fischer), Chester	Fischer Katz	North Sea Herring, Sydney	1887	Fischer, '87. Beyerinck, '90. Lehmann, '89. Tollhausen, '89. Katz, '91. Barnard, '99, Fig. Migula, '00, p. 433. Matzuschita, '02, p. 374. Miquel and Cambier, '02, p. 885.
Microspira annularis (Fischer), Mig.	Photob. annulare, Fischer Microspira annulare, Fischer, Mig.	Fischer	English Channel	1889	Fischer, '94. Migula, '00, p. 1014.
Microspira coronata (Fischer), Mig.	Photob. coronatum, Fischer B. phosphorescens coronatus, Matz. Microspira coronata (Fischer), Mig.	Fischer	English Channel	1889	Fischer, '94. Migula, '00, p. 1014. Matzuschita, '02, p. 76.
Microspira degenerans (Fischer), Mig.	Photob. degenerans, Fischer Microspira degenerans, Fischer, Mig.	Fischer	North Sea	1889	Fischer, '94. Migula, '00, p. 1015.
Bacillus tuberosus, Fischer	Photob. tuberosum, Fischer Microspira tuberosa (Fischer), Mig.	Fischer	North Sea	1889	Fischer, '94. Migula, '00, p. 1014.
Bacillus hirsutus, Fischer	Photob. hirsutum, Fischer	Fischer	North Sea, fish	1889	Fischer, '94.
Pseudomonas javanica (Eij.), Mig.	Photob. javanense, Eijkmann B. javanensis, Matz.	Eijkmann	Fish, Java	1891	Eijkmann, '92. Migula, '00, p. 953. Matzuschita, '02, p. 338.
Microspira caraibica (Fischer), Mig.	Photob. caraibicum, Fischer B. phosphorescens, caraibicus, Matz.	Fischer	Caribbean Sea	1889	Fischer, '94. Migula, '00, p. 1015. Matzuschita, '02, p. 340.
Microspira Dunbar, Mig.	Photospirillum, Dunbari Vibrio, Dunbari Vibrio phosphorescens, Dunbari-Rumpel Vibrio albensis, L. and N. Phosphorescent elbe vibrio, Kutscher and Dunbari	Dunbar	River Elbe, Hamburg	1889	Dunbar, '93. Kutscher, '95. Migula, '00, p. 1013, Fig. Lehm. and Neum., '01, p. 370, Fig. Matzuschita, '02, p. 108.
Microspira luminosa (Bey.), Mig.	B. luminosa, Kruse B. phosphorens (Katz), Mig. B. argenteo-phosphorescens liquefaciens, Katz Photob. luminosum, Bey. Vibrio luminosus (Bey.), L. and N.	Beyerinck Katz	North Sea Fish, Delft	1888 1887	Beyerinck, '89. Katz, '91. Flugge, '96, p. 331. Migula, '00, p. 1015. Lehm. and Neum., '01, p. 371 Matzuschita, '02, p. 76. Miquel and Cambier, '02, p. 884.
Microspira glutinosa (Fischer), Mig.	Photob. glutinosum, Fischer	Fischer	North Sea English Channel	1889	Fischer, '94. Migula, '00, p. 1014.
	IMPERFECTLY DESCRIBED.				
Bacterium pholas, Dubois		Dubois	Pholas		
Bacterium pelagia Dubois		Dubois			
Bacterium saycophilum		Dubois	Lyon, France, meat	1891	Dubois, '98, Fig.
Microspira delgadensis (Fischer), Mig.	Photob. delgadense, Fischer	Fischer	Water and fish, Ponta Delgada	1889	Fischer, '94. Migula, '00, p. 1014
Microspira papillaris (Fischer), Mig.	Photob papillare, Fischer	Fischer	North Sea	1889	Fischer, '94. Migula '00, p 1016

frequent. The writer once saw it off the coast of Nova Scotia, about ten miles off shore from the entrance to Liverpool Bay, so thick on the surface that it made the water as smooth as glass and prevented a fair, full-sail breeze from rippling the water. As the breeze rose with the advancing day it was able to mark the water with occasional cat's-paws, and finally became strong enough to throw it into ripples. A tow net of finest bolting cloth, when dragged a few yards through this water, became filled with several pints of a clear, somewhat mushy jelly which was composed almost exclusively of *Ceratium*. Unfortunately no observations were made on the luminosity during the succeeding night.

Many of the investigators mentioned above have determined the fact that *Ceratium tripos* actually does produce light. Molisch picked out several individuals and placed them living in sea-water on a slide under the low power of the microscope, and by stimulating them by various chemical means, as alcohol, distilled water, acids, etc., caused them to show their light.

Zacharias, while studying them in Kiel harbor in Germany, noted that they never lighted spontaneously, but only when they hit one another or collided with some other object. Thus they appear to shine only when disturbed by some chemical, mechanical, or other stimulus. The writer and Mr. Carl Speidel spent some time in careful observations on this form at Harpswell, Maine, in 1915. They were fairly abundant on the surface at night in the surrounding sea, and extended to the beach. Their light was very easy to compare with the light of the numerous young Ctenophores in the water. While the Ctenophore light was brilliant green, that of the strongly-stimulated *Ceratium* was silvery white. The creatures were shining all around the resting rowboat in occasional sparks, probably caused by their mutual collisions. When a medium coarse bolting-cloth net was drawn through the water a shower of silver sparks formed a brilliant spray in its wake, while the larger Ctenophores showed their bright green light as they stuck in the meshes.

Ceratium was evidently first stimulated as it was roughly drawn by the current through the meshes of the net, the stimulus consisting of its contact with the hard silk threads. It did not light until it was about 10 mm. past the net. Then came the flash, which lasted for from eighteen inches to two feet from the net. Thus the flash was not of one second's duration, although probably nearly as long as that short time. An after-glow of a faint greenish light persisted after the flash as the organisms were swept further behind the net by its motion through the water. It is thought that the first flash seemed white or silvery mostly because of its brightness or strength, but partly because of a different quality of its light waves.

A second method of lighting was also observed. When the plankton was towed at night and brought into the laboratory in a bucket of sea-water the *Ceratium* were lifted out of water on the hand or on a bit of clean cloth or paper. When thus caught and held captive they glowed for several seconds to several minutes with a weaker greenish light that still was not as green as that of the *Ctenophores*. This was probably their death-glow or glow of exhaustion.

Zacharias made an interesting observation on the periodicity of the light power. He found that from early daylight until 5 o'clock in the afternoon *Ceratium* was entirely unable to light. Only after 5 P.M. (by which time it was dark at that season of the year in Kiel) did the light power develop. The writer and Mr. Speidel have observed the same fact at Harpswell, Maine, when the *Ceratium* did not begin to light in early dusk, but only after real summer darkness had set in. We know that the bacteria shine continuously night or day, in light or darkness.

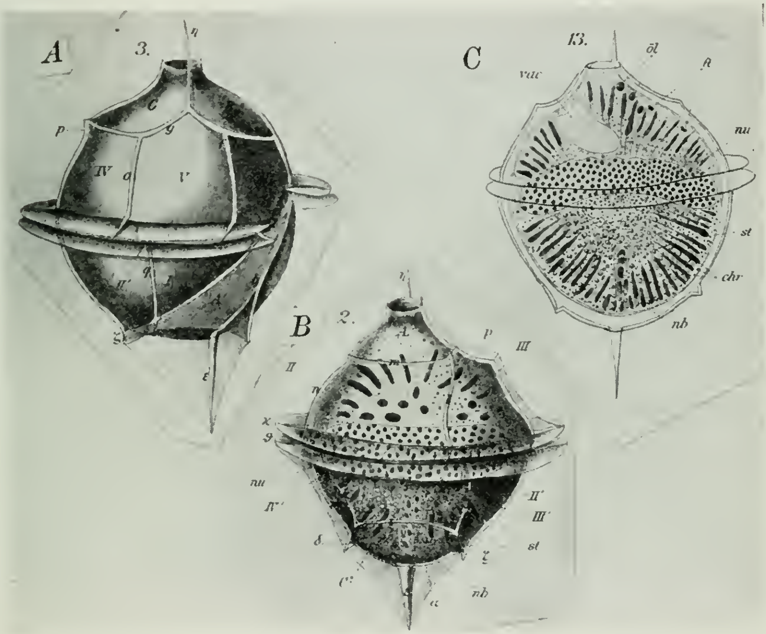
Many species of *Peridiniaceæ* live in fresh water, and some of them are much of the same form and structure as salt-water forms. These fresh-water forms have been carefully investigated, and it has apparently been proved that none of them has the power of light production. The form *Peridinium bahamense* was first described in 1906 by L. Plate from the "fire-lake" on the island of New Providence, in the Bahama Archipelago. In this little lake of salt water with an inlet to the sea is nightly to be seen a beautiful exhibition of light. The source of the light is, without doubt, the great mass of unicellular Dinoflagellates, *Peridinium bahamense*, which Plate found here (Fig. 7).

Plate shows that these organisms respond to all chemical and mechanical or physical stimuli with a flash of light. He feels, although he has not proved it, that the flash of light may sometimes be spontaneous.

It is of interest to note at this point that Plate describes the light of this form as "silver-white," thus making it agree with the light of *Ceratium tripos* as observed by the writer and Mr. Speidel. Perhaps the most interesting part of Plate's work is a careful description of the cytoplasm and nucleus of *Peridinium,* with some remarks on the probable seat of luminosity.

The organism has a compact, round, protoplasmic body containing a large nucleus whose shape can best be described as like that of a very short, thick sausage bent sharply into a semicircle and placed with the plane of the curve almost coinciding with the equatorial plane of the organism. The flagellum groove lies in this plane.

FIG. 7.

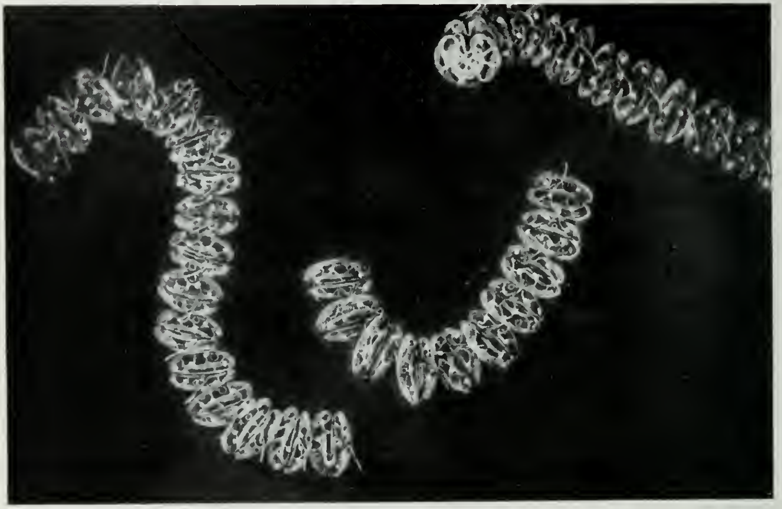


Drawings of *Peridinium bahamense.* A. View of the outside as an opaque object. B. View of organism as a transparent object. C. View of a median vertical section. *nu*, Nucleus; *nb*, nebenkoerper; *chr.*, chromatophores; *ft*, fat drops; *ol*, upper oil drops; *ub*, lower oil drops. (After Ludwig Plate.)

Radiating out in the cytoplasm from an approximate centre are a series of elongate bodies, the chromatophores, which bear a brown pigment. These bodies probably have nothing to do with the production of light. Besides these, however, are a series of other inclusions, the *nebenkoerper,* the anterior oil drops, the fat bodies, and the posterior fat drops, as well as one large, fluid-filled vacuole. We can dismiss the vacuole as a probable excretory organ, and as such not a directly active body in the production of light.

The *nebenkoerper,* however, from its position and unusual structure, might be the origin of the luminosity. Plate thought that he could see that the light came from the posterior part of the body. Until we know more of the microchemistry of luciferine, or until we can actually see the light emanating from the *nebenkoerper* or its surrounding fat droplets, it will not be possible to say which of these bodies are the ones that shine.

FIG. 8.



Photograph of a drawing of a colonial peridinium from the waters of lower Chesapeake Bay, as they appeared when luminous under a low magnification. (Drawn by E. Grace White.)

The last example of this large group that should be discussed here is the colonial form of the group *Peridiniaceæ,* seen by the writer in the waters of Delaware and Chesapeake Bays. This organism is figured as living and shining in Fig. 8. In life it is of a reddish-brown color and very small. The long, eel-shaped colonies, sometimes consisting of hundreds of individuals, swim in stately curved paths through the water, each individual always passing through the same spot that the leader did, no matter how many curves have been described by the colony. The larger colonies are easily separated into smaller units.

In the daytime the creatures form large patches of reddish water, from a few feet across to several acres. The fishermen at Norfolk told the writer that this reddish water was fresh water from the Dismal Swamp, tinged red with the tannin and coloring matter from the cypress and oak leaves, and that this water was boiling up from underground streams that opened into the bottom of the bay. A glassful of the reddish water and a Coddington lens soon showed that the color was due to the organism under consideration, and not to the Dismal Swamp.

It was remarkable how the creatures remained in each other's company and did not get generally distributed through the water by the swift currents and waves of the region.

While a passenger on a steamer that traversed these same waters in the night the writer saw one of the most beautiful exhibitions of luminosity imaginable. The boat would enter (by inference) one of the patches of red water and her bow and stern waves, as well as the friction water along the sides and the wake, were a mass of bright green fire. Also the roughening sea showed every tiny wavelet with its crest and back slope alight. The light was so bright that passengers in their state-rooms, with windows opening on the sides, saw the light reflected on the ceiling of the state-room and asked afterward what light we had passed or what steamer with her lights lit. The noticeable thing about this light was its vivid green quality, as well as the fact that it lasted longer than the silvery light of *Ceratium tripos.*

A polar view of a single member of the colony (Fig. 9) shows a large number of vacuoles containing some substance which is not a real fat (does not blacken with osmic acid) and which the writer believes to be luciferine.

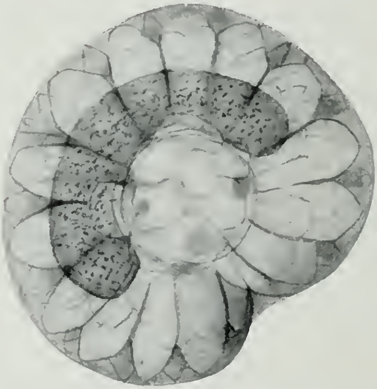
The *Cystoflagellata* are perhaps our best and most classic example of one-celled, light-bearing organisms. They shine the brightest, are perhaps largest, and have been known longest. Also more eminent scientists have studied them and published careful work concerning the light-producing power.

The animals are large for unicellular forms, and the entire group consists of only a few genera, all of which are luminous. These kinds are *Noctiluca, Pyrocystis, Leptodiscus,* and *Craspedotella.*

Of these few forms we will consider only the first, *Noctiluca miliaris,* Suriray, which was known to be a luminous creature of the ocean's surface as long ago as 1717 by Dartons de Mairan. Many have studied this form since, and the more casual studies, reports, and observations are so numerous that we will note only the more recent and important ones here.

Ehrenberg isolated this organism from other forms on the surface of the North Sea in 1834, and observed them sparkling and shining in a watch-glass full of sea-water. By using brandy, spring water, heated sea-water, or shaking as a stimulus, he saw the creatures respond with their flash and glow of light.

FIG. 9.



Polar end view of a single member of a colonial peridinium from Chesapeake Bay. Transparent view of Flemming fixation. The curved, sausage-shaped nucleus partly surrounds a central clear area, while the large vacuoles radiate out from this area. × 175. (Drawing by E. Grace White.)

It was Quatrefages who in 1850 studied *Noctiluca* most carefully and discovered some very important facts about their luminosity.

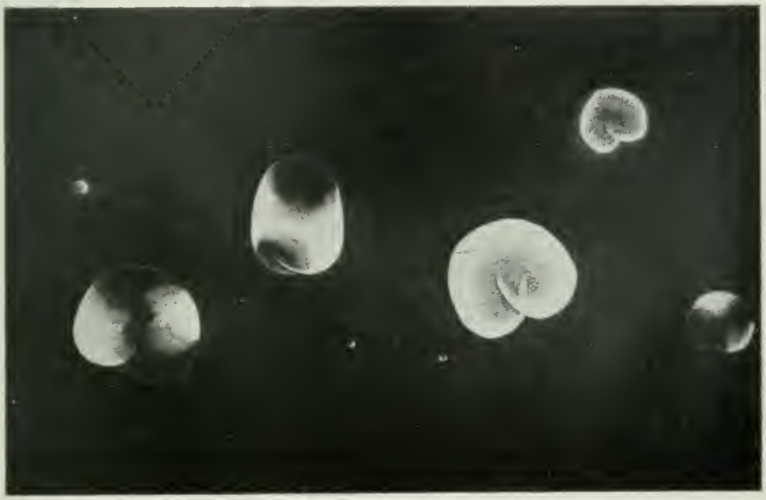
One of the most interesting pieces of work done on *Noctiluca* was his study of the creature under the microscope. When seen under a low magnification, even, it was perceived that the whole body did not shine, although the illuminated part appeared of a solid brilliancy. The light seemed superficial and was confined under ordinary stimulus to a spot covering about one-sixth of the entire surface. When magnified thirty times this spot could be well seen, and it was noticed that two such spots were on the surface and that they moved (Fig. 10) around on opposite sides.

When greatly disturbed these spots were extended until the whole surface was aglow, but this could continue for only a short time.

Quatrefages then magnified the animal with a higher-powered lens to 60 times, and saw the lighted "blush" of the *Noctiluca* as a milk-white ground with a number of shining points on it. Again he increased the magnification to 150 times, and then saw clearly that the entire luminosity was due to a vast number of tiny points from which the light streamed (Fig. 11).

These points were constant in position and were lighting up one after another on the side of the blush which was advancing, and also they were going out on the side that was receding. Thus the luminous area advanced in a steady progress, although the actual spots that composed it were fixed organs in which the luciferine was secreted and used. In this way the organism is able to remain illuminated for a considerable time.

FIG. 10.



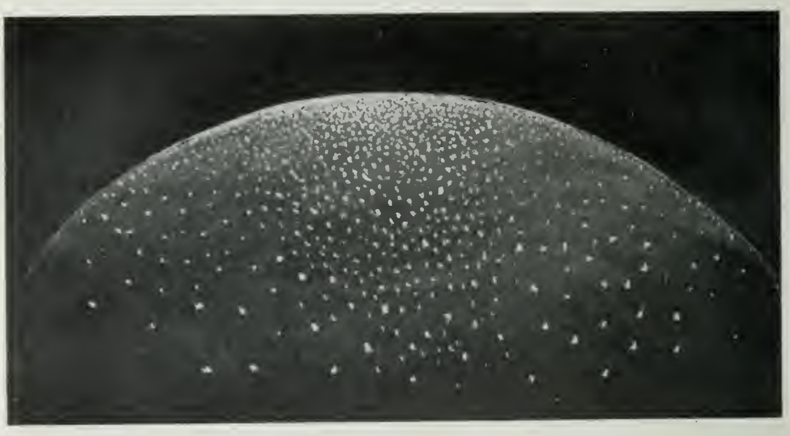
Photograph of a drawing representing *Noctiluca miliaris* as it appears when lighting. (Original.) × 30.

Noctiluca is extremely abundant in most seas at certain times and, owing to its red pigment, it may color the water various shades of red, sometimes blood-red. In the surface water of the North Sea they are sometimes so abundant that a glassful of water will show one-seventh of its bulk to be *Noctilucas*.

Quatrefages describes very beautifully the appearance at night of certain small bodies of water on the coast of France in which *Noctiluca* is the principal source of light. He describes the still black waters, and how a grain of sand thrown in will produce a small spot of light, how a stone will send out ripples of light, and how the constant friction of the small wavelets or swell on the sandy shores is the cause of a border of sparkling light to the dark pool. He mentions this light as silvery-white. We thus see that it apparently corresponds to a degree with the color of the light of the Dinoflagellates.

One of the first experiments tried by Quatrefages was to see if the luminous material secreted by the animal was discharged from the body. To do this he filtered a large basin of water containing thousands of the creatures through a sieve that was just fine enough to hold the animals back. The water that ran through the sieve showed no light, which was accepted as proof that the luciferine was kept inside the body during combustion. His observations on the source of the light as described on a previous page also confirm this.

FIG. 11.



View of *Noctiluca miliaris* under a magnification of 200 diameters to show that its light originates as a series of light points that make up the superficial wave of light or "blush" that travels over its body. (After Quatrefages.)

He also found that small portions of the animal's flesh cut apart from the body continued to light as though nothing had happened. A more important experiment was to fill a tall glass vessel with water that was laden with *Noctiluca*. These organisms rose to the surface as a thick layer, and the under ones continued to light as brilliantly as those on the surface when stimulated. Quatrefages believed that the numerous lower layers had used up the air in the surrounding water and were lighting in the absence of air. The writer does not agree with this, and would insist that the experiment be tried under more exact conditions before such a result is accepted.

The experiments to determine the intensity of the light were interesting, although lacking such accuracy, for instance, as Lode's more recent experiments with bacteria that were described in a previous chapter. Quatrefages filled a tube 15 mm. in diameter to a depth of 10 mm. with the living organisms and then compared their light under strong stimulation with that of a common household candle. He states that the lights were about equal. This at least shows great brilliancy for *Noctiluca*, since the surface dimensions of an ordinary candle flame and that of this mass of Noctilucas must have been in some degree comparable, if not equal.

Another point of great interest was the interesting observations made by this gifted scientist on the two different methods of lighting shown by *Noctiluca*. The first has been described already in a preceding paragraph of this article as the lighting up of a part, or possibly of the entire surface, of *Noctiluca* by the sharp flashing and shining of distinct points that worked in unison. The second only appears as an antemortem condition, and consists of the pale, continuous shining of all possible points of the animal's surface. This condition may last for several minutes or until death has set in. The writer has observed and mentioned on a preceding page a somewhat similar condition in *Ceratium tripos*.

Quatrefages also noted that whatever stimulus caused light also caused motion. The writer can see that this is probably true, but does not believe that the two processes are inseparable. We know that motion does take place without light, and I am quite sure that the light may take place without motion.

Besides these three forms of protozoa which produce so beautiful a light, no other one-celled organisms besides the bacteria can do the same. At least a careful search has shown plenty of other protozoön forms in the sea, but no light bearers among them. Perhaps others may be found by future investigators.

(*To be continued.*)

Poisons Used in the Rubber Industry. ANON. (*United States Commerce Reports*, No. 262, November 8, 1915.)—Rubber manufacture involves the use of numerous poisonous substances, of which lead salts, antimony pentasulphide, aniline oil, carbon disulphide, and carbon tetrachloride are the most dangerous. The operations involving exposure to these poisons, however, employ but a small proportion of the large number of workers. No women and very few boys are engaged in such operations. A lesser danger is found in the use of coal-tar benzol and of various petroleum products, such as naphtha, benzine, etc. A considerable number of the workers, including women and boys, are exposed to the fumes of these compounds. These facts are brought out in an investigation by Dr. Alice Hamilton of the industrial poisons used in the rubber industry, the results of which have just been published as Bulletin 179 of the Bureau of Labor Statistics of the Department of Labor.

While it was impossible to get complete data as to the frequency of industrial poisoning in the rubber industry, records were secured of no less than 66 cases of lead poisoning which occurred in 1914 among the rubber workers in the United States. Cases were also found of naphtha poisoning, and of poisoning from carbon disulphide, carbon tetrachloride, and aniline oil.

The dangerous nature of some of the compounds used in the rubber industry is not yet commonly known, so that cases of industrial poisoning may occur without being recognized as such and ascribed to their true cause. Also, in the case of some of the compounds, the symptoms of poisoning may be obscure or may not develop until some time after the exposure has taken place, so that again the resulting harm may not be ascribed to its true cause.

The investigation on which the bureau's report is based covered 35 rubber factories, located in 15 cities or towns in 9 States. Practically every branch of the rubber industry was included among the activities of these factories. As there are many trade secrets in the manufacture of rubber articles, it was impossible to make the investigation as complete as was desired.

It is possible to equip and manage a rubber factory so that exposure to the various industrial poisons will be reduced to an insignificant minimum or wholly eliminated. Relatively little, however, seems to have been done in this direction.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

MEASUREMENTS FOR THE HOUSEHOLD.[1]

The purpose of Circular No. 55, just issued by the Bureau of Standards, is (1) to give information as to units, methods, and instruments of measurement useful in household activities, (2) to describe available means of assuring correct quantity in articles bought by weight and measure, and (3) to give other facts of interest which would awaken an appreciation of the rôle of measurement in daily life.

In the scientific investigations of numerous questions the Bureau of Standards has accumulated general information which may be known to the industries concerned, and hence of less novelty to them, but is often of great value and importance to the general public. For example, watchmakers are familiar with the construction and adjustment of watches and clocks, and the best methods of caring for them, but the ordinary purchaser who uses them is often at a loss to obtain the most elementary knowledge of how to properly care for them. In the same way, to electrical and gas engineers information given in this circular is everyday knowledge, but the householder, while deeply concerned about the indications of his meters and the quality of the gas supplied to him, often finds it difficult, if not impossible, to secure simple technical information that is often of great value to him. It was with the purpose of making the results of the work of the Bureau available to the public in so far as this work is related to the work of the household that this circular has been prepared.

RÔLE OF MEASUREMENT IN DAILY LIFE.

Household measurements suggest many interesting phases of the art of measurement. The significance of measurements in our civilization and their effect upon everyday life may not be fully appreciated. From the beginning of life measurement is important. The infant should weigh about so much, and the number of pounds is one measure of its condition. Its weight should increase at a normal rate, and here the weight becomes an index of nutrition and good health. The measure of body temperature is an advance indicator of illness. Especially in recent scientific studies of childhood is the importance of measurement keenly realized. The repsonse of muscles and nerves—the measure of the so-called time reactions and sense perception—are elements in studying educational methods, especially subnormal cases. It is possible to set certain approximate standards for the normal child and its growth. Measurements are made of the speed, strength, and fatigue of its reactions; of its height, girth, and other dimensions. Muscle measures and strength tests indicate normal growth or the effectiveness of physical training. The ergograph measures endurance, and the chronograph records perceptions and reaction times. The focusing power of the eyes is measured, and with these measurements the optician can perfect the vision by adapting the measured curvature of glass to the measured defect of vision. The correct measures of the body determine the comfort and effectiveness of clothing.

---

* Communicated by the Director.

[1] Circular 55, Bureau of Standards, Washington, D. C.

Modern industry owes its efficiency largely to careful measurements which control processes, or fix the dimensions, proportions, and properties of products. Accurate parts of machines or accessories make it possible to manufacture the parts separately and assemble them without special hand fitting. Any one may then order repair parts, knowing that they will fit into the machine. In many industries the measured control of heat, electric current, or power is essential to efficient operation. Bread should rise at a definite temperature, steel should be quenched at a certain stage in cooling to give the best results, and similar account must be taken of many things to secure the desired quality.

Properties of materials are measured or tested, and this gives a means of controlling quality. Measurement guides the processes of all industries and keeps their output up to certain standards. Careful determinations of the properties of materials are coming to mean more and more to business and industry, and the determination of properties of standard materials is an ever-increasing part of the work of this Bureau.

MEASURES OF TRADE AND THEIR INSPECTION.

The Bureau of Standards is also active in the phase of measurements that touches the household very directly—the weighing and measuring of goods bought, sold, and transported. Much inaccuracy and fraud exist. Weights and standards and instruments are subject to accident, deterioration, and tampering. For these reasons systematic inspection of trade weights and measures is regarded as a function of the government. In order that the standards throughout a country should be uniform, the custody of the fundamental standards rests with the National Government, which is authorized to fix the standards of weight and measure. In the United States the actual inspection service, being necessarily local, has been left to the States and cities. This Bureau's work has been (1) to provide the States with standardized sets of weights and measures, (2) to encourage and stimulate intelligent interest in the State and local regulation and inspection of weights and measures, (3) to coöperate with the local sealers regarding the technical details of inspection service, and (4) to gather data regarding the standards and instruments in use.

MEASUREMENTS OF HOUSEHOLD PRODUCTS AND PROCESSES.

Improved precision has slowly evolved from the guesswork of earlier times. For example, terms like the "pinch of salt," "speck of pepper," "handful of rice," "sweeten to taste" (units of vague magnitude) have gradually been replaced by definite amounts specified and measured. A process is uncertain of success unless the effect of all the factors entering into it is known. In factories where food is prepared on a large scale, temperatures are carefully measured or determined automatically, and amounts and times are accurately controlled. These methods, which make for efficiency and economy, are being used more and more in the household.

Such measurements as require costly or delicate apparatus can not yet be expected to be common in the home; and some still think that the measurement of temperature of rooms, of ovens and syrups, and the weighing of purchases, etc., are unimportant. However, scales, thermometers, and a few other simple measuring appliances can be obtained for a small expenditure, and this circular will attempt to show some of the advantages of their use. Measuring instruments for household use which are automatic, or which may easily be operated without special training, are becoming more and more available.

HOUSEHOLD MEASURING APPLIANCES.

A large variety of measuring appliances are used in connection with the household work. A description of the kinds of appliances will be found in more or less detail in the several sections of this circular; they include the following groups:

1. A test set of weights and measures for checking purchases and other purposes.
2. Meters for measuring the delivery for household use of gas, water, and electricity.
3. Special measuring instruments, such as thermometers, hygrometers, barometers, hydrometers, and timepieces, for measuring temperature, moisture, pressure, density, and time.
4. Special measures used in cooking.

The efficient management of the modern household is greatly promoted by the careful use of well-selected measuring appliances, and one of the purposes of this circular is to guide the housewife in the selection and use of such appliances.

EDUCATIONAL VALUE OF HOUSEHOLD MEASUREMENTS.

Apart from the direct use of the results of measurements in the household, they are, when properly made, of educational value. Hazy ideas of process and dimension become clear and definiteness of thought is gained. Opportunities for measurement are a means of education for children which should not be ignored. The habit of thinking in terms of units and definite quantities can not fail to increase the efficiency of the individual and the household. The practical measurement of purchases may be made a means of education in appreciating and estimating quantities. Boys may easily construct rough measuring instruments and devise methods of measurement of such things as air-pressure, wind velocity, temperature, etc. The measurement of areas and volumes of rooms; the heights and weights of individuals; of the growth of children, etc., are all matters which lend themselves to educational uses. Some of the information given in the chapters of this circular, for example, on light, on gas meters, on the use of clocks, on humidity, etc., may lead to observations and experiments of considerable educational value. In general, it may be said that the educational and other uses of household measurements are almost unlimited and but little realized.

UNITS AND TABLES.

In the appendix will be found tables of units and special data regarding measurements. Many of the units used are somewhat vague and in some cases the terms are ambiguous. For example, the *ounce* used in the drug store is not the same as the ounce used in the grocery store, even when the same commodity is purchased, and the *fluidounce* is different from either, and is not a weight at all. It will thus be seen that for more careful work in connection with measurements the exact value of the units used should be clearly known. The growing use of the metric system throughout the world is rapidly introducing simplicity and definiteness in place of existing confusion, since in that system there is but one name for each unit and the unit has but one value throughout the world. Since the American Pharmacopœia now uses the metric system as the only system of measurement in the formulas for drugs and medicines, a knowledge of the metric system is increasingly desirable, especially in connection with the prescription and use of medicine and other compounds. In domestic science and related sciences the knowledge of the metric system is indispensable to the best work, since everywhere the more technical aspects of these subjects usually involve the use of the metric system. A pamphlet descriptive of the metric system may be obtained upon application to this Bureau.

Measuring the Discharge through a Venturi Tube with a Direct Reading Meter. J. DEJUST. (*Comptes Rendus,* vol. 161, No. 16, October 18, 1915.)—The method here proposed for measuring the discharge consists in replacing the usual apparatus for measuring the pressure difference between the full and the contracted sections of the tube and the integrating mechanism with an ordinary meter. The difference in pressure between the large and small sections of the tube causes a discharge between these two points.

The intake of the meter is directly connected to the full up-stream section of the tube; between the outlet and the down-stream contracted section of the tube a diaphragm is introduced. The algebraic expression of the ratio of the discharge through the tube to that through the by-pass containing the meter shows that this ratio is not constant. By adjusting the section of the by-pass tube and its diaphragm, however, the terms which are not constant can be reduced to a negligible value and the ratio made substantially constant for various rates of discharge. The constancy of this ratio has been tested on a line 100 mm. in diameter, provided with a Venturi tube having a contraction of 16 to 1, with a by-pass 20 mm. in diameter, a meter orifice of 12 mm., and a diaphragm calculated to make the ratio of meter discharge to flow through the line, 1 to 100. By varying the velocity in the line from 0.16 meter to 1.23 meters, the ratio varied from 103.82 to 105.53; that is to say, 1.65 per cent. of the smaller number. Reckoning from the mean of these two values, 104.675, the maximum error will be 0.82 per cent. of the true discharge.

Water Powers of the Cascades. ANON. (*United States Geological Survey Water-Supply Papers Nos. 253 and 313.*)—Well to the west of the great rock barrier which in the early days of the Republic was assumed to be the natural western boundary of the United States lies another great belt of elevated land surmounted by a chaos of rugged peaks and pyramids—the Cascade Range of Washington and Oregon. In these mountains there is an inexhaustible store of potential wealth, much of it belonging to the nation—not precious or useful metals, for mines, however rich, must eventually become exhausted, but a wealth of running water, an endless chain revolving with the seasons. The streams of the Cascades possess in high degree the requisite characteristics for the successful development of water power; namely, steep gradient, abundant water, and comparatively uniform flow. Add to these the enormous resources of timber, metallic and other minerals, and lands as yet developed only in small part but promising an extensive future market for water power, and it becomes apparent that the large areas of country surrounding the Cascade Plateau have in the undeveloped power of their streams very great potential wealth.

The United States Geological Survey, in coöperation with the Washington State Board of Geological Survey, has made a comprehensive survey of the water resources of this area in that State. Water-Supply Paper 313, issued by the Federal Survey, entitled "Water Powers of the Cascade Range, Part II," is the second of a series of reports resulting from this work, the first having been issued as Water-Supply Paper 253. This second report deals principally with the drainage basins of Cowlitz, Nasqually, Puyallup, White, Green, and Cedar Rivers. It includes all monthly estimates of river discharge derived from data collected by the water-resources branch of the Geological Survey in coöperation with the State Board of Geological Survey and by private persons.

The summaries of the available power in each basin are computed from the average flow for the lowest week on record and from the flow that could be realized from possible storage. The flow with storage is computed on the basis of the continuous discharge that can be maintained by the release of the stored water during the most extreme drought on record, considering the length and severity of low-water periods.

NOTES FROM NELA RESEARCH LABORATORY.*

VISUAL PATTERN-DISCRIMINATION IN THE VERTEBRATES. IV.—EFFECTIVE DIFFERENCES IN DIRECTION OF VISIBLE STRIÆ FOR THE MONKEY AND THE DOMESTIC CHICK.[1]

By H. M. Johnson.

THE following experiments were made by the Yerkes-Watson discrimination-method on one Capuchin monkey and two Indian gamecocks. The discriminants were two circular fields 6 cm. in diameter, 6.2 candles per square metre in mean brightness, the spectral distribution approximating that of a tungsten lamp operated at a specific consumption of 1.25 watts per candle. Both fields were covered with alternate dark and bright striæ equal in width and separation, and distinguishable by the animals as such under the experimental conditions. The striæ on the positive field were horizontal; those on the negative field deviated from the horizontal direction by a definite and variable amount. In the beginning of the training the difference was 90 degrees, and was decreased by small gradations after the animal had formed a perfect discrimination-habit.

One chick failed to learn the problem in 800 trials. A second chick established a perfect habit in 585 trials distributed over 58 days. There was consistent improvement after 280 trials. The monkey learned the problem in the first daily series of 20 trials, during which he made but two errors.

The difference in direction effective in half the total number of trials, as shown by an average percentage of correct choices of 75, is between 2 degrees and 5 degrees for the monkey and between 25 degrees and 40 degrees for the chick. The magnitude of the threshold between these limits depends in large part on the effect of practice.

The training records, as well as the final results, suggest that difference in direction is a much more significant characteristic for the monkey than for the chicken.

The relative improvement brought about by training is very much greater for the monkey than for the chicken. This fact suggests that in discrimination of this type other differential factors than relative development of the sense-organ play an important part. The point is emphasized by the fact that the monkey's visual acuity was demonstrated to be not over five times as good as that of the chicken, while his sensitivity to differences in direction is from eight to twelve times as great.

---

* Communicated by the Director.

[1] To appear in the *Journal of Animal Behavior*.

VISUAL PATTERN-DISCRIMINATION IN THE VERTEBRATES. A DEMONSTRATION OF THE DOG'S DEFICIENCY IN DETAIL-VISION.[1]

By H. M. Johnson.

SOME years ago the writer made some lengthy experiments[2] on the rate and methods of acquiring skill of blind, temporarily blind, and normal dogs, and accumulated quite a mass of evidence that in learning to make quite complicated adjustments the dog makes but little use of vision. There was also some evidence that in uncontrolled behavior dogs react to many ordinary objects as if the latter were not visually perceived. These data emphasized the interest of the question as to the kind and degree of vision which the dog may have.

In the year 1911–12 I attempted to train a dog by the discrimination-method of Yerkes and Watson to discriminate between a circle 6 cm. in diameter and its approximately equivalent square. In the preliminary training I presented a 4 to 1 difference in brightness (which in this case made a 4 to 1 difference in luminous intensity) in addition to the difference in outline of the two objects. Under these conditions the dog established discrimination in 1000 trials. When the two fields were equated in brightness he ceased to discriminate, and showed no preference for the positive field in 600 additional trials.

In the present work I used a pure-bred English bull-terrier with two emmetropic eyes. The first attempt made was to train him by the Yerkes-Watson method to choose a food-box indicated by a field covered by coarse stripes, and to avoid, under penalty of an electric shock, a food-box indicated by a field of uniform brightness. The two fields were, of course, interchangeable with reference to the food-boxes, and were equal in area, outline, and mean brightness, the latter being 12.2 candles per square metre. The animal was required to choose at a minimal distance between test-object and eye of 60 cm. He failed to learn the problem in 1200 trials, although the pattern on the "positive" field was quite coarse. A monkey and two chickens trained under comparable conditions established a perfect habit in from 200 trials to 400 trials each.

---

[1] To appear in the *Journal of Animal Behavior.*

[2] Johnson, H. M.: "Audition and Habit-formation in the Dog," Behavior Monograph No. 8. Cambridge, Mass., Henry Holt & Company, 1913.

I then presented a difference in area in addition to the difference in distribution of brightness over the fields, and the animal acquired a perfect habit very quickly. Control tests showed that the difference in pattern was ineffective, as the animal's responses were not affected in accuracy by eliminating that difference. The effective difference in area was between 2.25 to 1 and 1.44 to 1. Since the two fields were of equal brightness, this difference in area resulted in a corresponding difference in luminous intensity. I now made the brightness of the test-fields inversely proportional to their areas, and the animal immediately ceased to discriminate. This indicated that his discrimination-habit had been based on difference of luminous intensity alone.

It now became necessary to ascertain and consider certain structural characteristics of the dog's eye considered as an optical system. There is a mechanism for accommodation as in the typical mammalian eye. According to Freytag, however, the refractive index of the lens is almost exactly the same as that of the fluid media. All the refraction undergone by an incident beam in such an eye must, therefore, take place at the cornea. Change of the radius of curvature of the lens would not in itself change the focal length. The eye is set for a single focal distance, and only objects at a given distance may be imaged on the retina. In this dog, parallel rays, or rays proceeding directly to the eye from an object 20 feet or more away, are brought to a focus on the retina. In the next experiment each test-object was mounted in the principal focus of a good projection lens. Under the experimental conditions a sharp image of the test-object was formed on the retina, no matter where the dog's eyes were placed in the cone emerging from the lens.

In this experiment the two fields were 6.2 candles per square metre in mean brightness, circular in form, and 6 cm. in diameter.

The positive field was covered by a system of alternate dark and bright stripes, each member of which subtended a visual angle of 33′ 32″. The negative field was of sensibly uniform brightness. The pattern on the positive field may be compared to that of a plank fence in which the planks are 6 inches wide and 6 inches apart, viewed at a distance of 50 feet. The dog did not learn to discriminate between these two fields and did not show a tendency to improve in 500 trials. Under the circumstances I regard his failure as conclusive evidence that he is unable to distinguish quite gross details in visual objects. Since the experimental conditions insured the formation of a sharp image on the retina, we must attribute his failure to relative insensitivity of that organ to distribution of brightnesses over it. There is no fovea in the dog's retina, the sensitive area is indefinite both in form and extent, and there are numerous branchings of opaque nerve-fibres which must be regarded as blind spots. As is suggested above, if accommodation is not impossible, its range must be extremely small. There is a tendency to gross errors of refraction, varying widely in different individuals. For many of them the retina can never be stimulated by a sharp image. It should not be inferred from the above that the dog's eye is a useless organ, for such a retina, like the peripheral region in the human retina, seems to be quite sensitive to movement of visual objects. This is probably the most important form of visual sensitivity which the dog possesses.

The structural characteristics of the dog's eye obtain among other carnivora and among ungulates and rodents. The foregoing results, considered in the light of comparative anatomy, suggest that we are not justified at present in attributing detail-vision to many other mammals below the primates.

THE FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting held Wednesday, November 17, 1915.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 17, 1915.

PRESIDENT WALTON CLARK *in the Chair.*

Additions to membership since last report, 8.

A report on the condition of the work of the Committee on Science and the Arts was presented.

Mr. G. H. Clamer, Chairman of the Committee on Science and the Arts, introduced Mr. Harold N. Anderson, of Cleveland, Ohio, and Mr. H. W. Hardinge, of New York City, to whom had been awarded the John Scott Legacy Medal and Premium by the City of Philadelphia on the recommendation of The Franklin Institute, the former for his Gear Rolling Machine and the latter for his Conical Pebble Mill. The medals were presented to Messrs. Anderson and Hardinge by the President.

A. A. Michelson, Ph.D., Sc.D., LL.D., Professor of Physics, Ryerson Physical Laboratory, University of Chicago, presented the paper of the evening, entitled "On the Ruling of Diffraction Gratings." The speaker reviewed the history of the ruling of gratings, and gave an account of the work of Rutherford, Rowland, and others. He pointed out the difficulties encountered in making gratings of large size and high resolving power, and described the devices employed for overcoming such difficulties, especially by the use of interference methods. Reference was also made to some of the modern problems requiring high resolving power. The subject was illustrated by lantern slides, specimens of gratings, and apparatus.

The Chairman requested Dr. Hoadley to preside during the discussion, in which Messrs. Saunders, Henderson, Levy, Bond and Drs. Goldsmith, Trowbridge, Barnes, Northrup, Goodspeed, and Ives participated. After a vote of thanks to the speaker the meeting adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, November 3, 1915.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 3, 1915.

DR. G. A. HOADLEY, *Chairman pro tem.*

The following reports were presented for first reading:

No. 2626.—Dorr's Hydrometallurgical Apparatus.
No. 2635.—Northrup's High Temperature Investigations.

The following report was presented for final action:

No. 2617.—Permutit. Final action on this report was deferred until next meeting.

The followinig report was presented for reconsideration:

No. 2636.—Lenker's L-E-Vation Rod. Reconsideration of this report was deferred until next meeting.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A joint meeting of the Section and of the Philadelphia Section of the American Chemical Society was held in the Hall of the Institute on Thursday, October 28, 1915, at 8 o'clock P.M., with Mr. C. C. Tutwiler in the chair. The minutes of the previous meeting were read and approved.

The presiding officer introduced Dr. Harlan S. Miner, chairman of the Philadelphia Section of the American Chemical Society, who then presented the speaker of the evening, Dr. Frank K. Cameron, of the Bureau of Soils, U. S. Department of Agriculture, Washington, D. C.

Dr. Cameron delivered an illustrated lecture on "The Development of a Dynamic Theory of Soil Fertility." The different static theories of soil fertility were reviewed, and the gradual evolution of the modern dynamic theory of soil fertility was traced. The various dynamic factors which influence the fertility of the soil were discussed. A vote of thanks was extended to Dr. Cameron, and his paper referred for publication. The meeting adjourned after an interesting and extended discussion.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A joint meeting of the Section and of the Philadelphia Section of the American Chemical Society was held in the Hall of the Institute on Thursday evening, November 4, 1915, at 8 o'clock, with Drs. Robert H. Bradbury and Harlan S. Miner, presidents of the two sections, presiding jointly. The minutes of the previous meeting were approved as read.

Charles H. Herty, Ph.D., Professor of Chemistry in the University of North Carolina and president of the American Chemical Society, delivered a lecture on the "Turpentine Industry in the Southern States." The old method of "boxing" the pine trees in order to collect the oleoresin, and the destruction of the forests as a consequence, were discussed. The new method of tapping the trees by means of troughs was described; the process is far less injurious to the trees, produces a greater yield of turpentine, and the rosin is of a higher grade. The present view of the physiology of the resin secretion and flow was presented. The lecture was illustrated with lantern slides and with specimens of the tools used and products obtained in the turpentine industry. The paper was discussed by Drs. Herty, Harshberger, and Remington, Messrs. Stratton, Levy, and Benoliel and others. A vote of thanks was extended to the lecturer and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A stated meeting of the Section was held in the Hall of the Institute on Thursday, November 11, 1915, at 8 o'clock P.M., with Dr. Gellert Alleman in the chair. The minutes of the previous meeting were approved as read.

Professor J. C. McLennan, Ph.D., F.R.S., Director of the Physical Laboratory of the University of Toronto, Canada, delivered a lecture on "Spectra, Their Origin and Some of their Characteristics." Series, resonance, fluorescence, and single-line spectra were described, as was the structure of the finest spectral lines. The best method for the production of metallic arcs was pointed out. The relationship between certain elements and their spectra, and the relationship between the quantum theory, spectra characteristics, and the structure of the atom, were discussed. The lecture was illustrated with lantern slides. After a discussion of the paper, a vote of thanks was extended to the lecturer, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

A RELATION CONCERNING THE DISTRIBUTION OF AN ELECTROLYTE BETWEEN WATER AND SOME SECOND SOLVENT AND ITS DISSOCIATION CONSTANT IN AQUEOUS SOLUTION.

CORRECTION.

SWARTHMORE COLLEGE,
Swarthmore, Pennsylvania,
Department of Chemistry.

November 16, 1915.

The Editor,
JOURNAL OF THE FRANKLIN INSTITUTE.

DEAR SIR:

I have just had my attention called to an error in my paper on "A Relation Concerning the Distribution of an Electrolyte between Water and Some

Second Solvent, etc.," which appears in the July, 1915, issue of the JOURNAL OF THE INSTITUTE. Equation (21), page 68, should read:

$$z=\frac{c'-c\sqrt[2n]{\frac{b'}{b}}}{\sqrt[n]{\frac{b'}{b}}-\sqrt[2n]{\frac{b'}{b}}}$$

and not:

$$z=\frac{c'-c\sqrt[2n]{\frac{b'}{b}}}{\sqrt{\frac{b'}{b}}-\sqrt[2n]{\frac{b'}{b}}}.$$

If this correction could be published in the December number of the JOURNAL, I should be obliged.

Yours very truly,

H. JERMAIN CREIGHTON.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, November 10, 1915.*)

RESIDENT.

MR. ARTHUR COLLINS, Atlas Ball Company, Second Street and Glenwood Avenue, Philadelphia, Pa.

MR. RICHARD HOWSON, Southwark Foundry and Machine Company, 430 Washington Avenue, Philadelphia, Pa.

DR. ARTHUR WELLS YALE, 2008 Walnut Street, Philadelphia, Pa.

NON-RESIDENT.

MR. ROBERT JOHN ANDERSON, School of Mines and Metallurgy, University of Missouri, Rolla, Mo.

MR. EUGENE E. AYERS, Sharples Specialty Company, West Chester, Pa.

MR. CHESTER LICHTENBERG, 138 Park Place, Schenectady, N. Y.

MR. LEGRAND PARISH, American Arch Company, 30 Church Street, New York, N. Y.

MR. ARTHUR W. THOMPSON, Baltimore and Ohio Railroad Company, Baltimore, Md.

CHANGES OF ADDRESS.

Chief Constructor W. L. CAPPS, care of Bureau of Construction and Repairs, Navy Department, Washington, D. C.

MR. J. H. GRANBERY, 312 West Twentieth Street, New York, N. Y.

MR. JOHN J. KOHLER, Devitts Camp, Allenwood, Union County, Pa.

PROF. J. AMBROSE MOYER, Director of Extension Service, Massachusetts Board of Education, Boston, Mass.

MR. CHARLES S. VADNER, 22½ South Seventh Street, West, Salt Lake City, Utah.

MR. WILLIAM CHATTIN WETHERILL, Keystone Screw Company, care of Frishmuth Brothers & Co., Seventeenth Street and Lehigh Avenue, Philadelphia, Pa.

NECROLOGY.

William Hunter, Philadelphia, Pa.

LIBRARY NOTES.

PURCHASES.

Deutsche Bunsen-Gesellschaft für angewandte physikalische Chemie. Abhandlungen. 1909–1911.

DOWD, ALBERT A.—Tools, Chucks and Fixtures. 1915.

DURHAM, HENRY W.—Street Paving and Maintenance in European Cities. 1913.

GREEN, ARTHUR G.—Analysis of Dyestuffs. 1915.

GUEST, JAMES J.—Grinding Machinery. 1915.

HAYS, JOSEPH W.—Combustion and Smokeless Furnaces. 1915.

HILL, G. F.—Development of Arabic Numerals in Europe. 1915.

McGraw Waterworks Directory. 1915.

Machinery Publishing Company.—Spiral and Worm Gearing. 1914.

McLEOD, ALEX.—Practical Instruction in the Search for, and the Determination of, the Useful Minerals, Including the Rare Ores. 1914.

MELLOR, J. W.—Treatise on Quantitative Inorganic Analysis.

TINKLER, C. K, and CHALLENGER, F.—Chemistry of Petroleum and its Substitutes. 1915.

WEBBER, W. H. Y.—Gas Supply in Principle and Practice. 1915.

GIFTS.

American Society of Civil Engineers, Transactions, vol. lxxviii. New York, 1915. (From the Secretary.)

American Society of Mechanical Engineers, Condensed Catalogues of Mechanical Equipment, 5th Annual Volume. New York, 1915. (From Dr. R. B. Owens.)

Appropriation Acts of the General Assembly of the Commonwealth of Pennsylvania. Harrisburg, 1915. (From the State Librarian.)

Association Francaise Pour L'Avancement des Sciences, Compte Rendu de la 42me Session, Tunis, 1913. Paris, 1914. (From the Association.)

Association of Railway Telegraph Superintendents, Proceedings. Milwaukee, Wis., 1915. (From the Association.)

Atlantic Coast Line Railroad Company, Seventy-first Annual Report. Richmond, 1905. (From Robert D. Jenks, Esq.)

Austin Brothers, Catalogue and Hand-Book. Dallas, Texas, no date. (From the Company.)

Blanchard, Arthur H., Elements of Highway Engineering. New York, 1915. (From the Author.)

Bombay Meteorological Office, Rainfall of the Bombay Presidency for Years Previous to 1891, vol. iii. Bombay, 1914. (From the Meteorologist.)

Boston Elevated Railway Company, Eighteenth Annual Report. Boston, 1915. (From the Company.)

Brooklyn Engineers' Club, Proceedings, 1914. Brooklyn, 1915. (From the Club.)

Buffalo, Rochester and Pittsburgh Railway Company, Twenty-first Annual Report. New York, 1906. (From Robert D. Jenks, Esq.)

Canada Department of Customs, Report. Ottawa, 1915. (From the Department.)

Canadian Society of Civil Engineers, Transactions, vol. xxix, part i. Montreal, 1915. (From the Society.)

Carnegie Steel Company, Shape Book, Catalogues of Steel Cross Ties, Steel Mine Timbers, Gear Blanks and Miscellaneous Circular Sections, Axles and Forgings, Steel Sheet Piling. Pittsburgh, no date. (From the Company.)

Chemical Rubber Company, Handbook of Chemistry and Physics. Cleveland, 1914. (From the Company.)

Chicago, Burlington and Quincy Railroad Company, Sixty-first Annual Report. Chicago, 1915. (From the Company.)

Connecticut Agricultural Experiment Station, Thirty-eighth Annual Report, 1914. Hartford, 1915. (From the Station.)

DuPont de Nemours Powder Company, Road Construction and Maintenance, Farmers' Handbook, Vertical Farming. Wilmington, 1915. (From the Company.)

Great Northern Railway Company, Twenty-sixth Annual Report. No place, 1915. (From the Comptroller.)

Hispanic Society of America, Catalogue of Mexican Majolica belonging to Mrs. Robert W. deForest. New York, 1911. (From the Society.)

India Department of Revenue and Agriculture, Quinquennial Review of Forest Administration in British India for the Period 1909–10 to 1913–14, to which is appended The Annual Return of Forest Statistics for the Year 1913–14. Simla, 1915. (From the Department.)

India Imperial Department of Agriculture, Progress of Agriculture in India for 1912–13. Calcutta, 1914. (From the Department.)

Industrielle Gesellschaft von Mülhausen, Jahresbericht, 1914, Zweiter Teil. Mulhausen, 1915. (From the Society.)

Ireland Institution of Civil Engineers, Transactions, vol. xli. Dublin, 1915. (From the Institution.)

Lake Mohonk Conference on International Arbitration, May 19, 20, and 21. Mohonk Lake, N. Y., 1915. (From the Conference.)

Laws of the General Assembly of the Commonwealth of Pennsylvania. Harrisburg, 1915. (From the State Librarian.)

Manchester Steam Users' Association for the Prevention of Steam Boiler Explosions, Memorandum by Chief Engineer, 1914. Manchester, 1915. (From the Association.)

Michigan Department of Labor, Thirty-second Annual Report. Lansing, 1915. (From the Department.)

National Academy of Sciences, Memoirs, vol. xii, part ii. Washington, 1915. (From the Academy.)

National Transcontinental Railway Investigating Commission Report, vols. i and ii. Ottawa, 1914. (From Robert D. Jenks, Esq.)

Niagara Frontier Car Men's Association, Proceedings, May, 1914, to August, 1915; September, 1915. Buffalo, no date. (From the Association.)

New Jersey State Board of Public Utility Commissioners, Fifth Annual Report, 1914, and Statistics of Public Utilities, 1913. Trenton, 1915. (From the Board.)

New York, New Haven and Hartford Railroad Company, Thirty-sixth and Forty-fourth Statements. New Haven, 1907 and 1915. (From Robert D. Jenks, Esq.)

New Zealand Government, 15 publications and map. Wellington, 1911–1914. (From Mr. E. Clifton, Commissioner at the Panama-Pacific Exposition.)

Northampton Polytechnic Institute, Announcements, 1915–16. London, no date. (From the Institute.)

Osaka Imperial Mint, Director's Report. Tokyo, 1915. (From the Director.)

Parke, Davis and Company, Collected Papers from the Research Laboratory, vol. 3. Detroit, 1915. (From the Company.)

Royal Philosophical Society of Glasgow, Proceedings, vol. xlv, 1913–1914. Glasgow, 1914. (From the Society.)

Southern Pacific Company and Proprietary Companies, Thirty-first Annual Report. New York, 1915. (From the Company.)

Southern Railway Company, Twenty-first Annual Report. Richmond, Va., 1915. (From the Company.)

Tasmania Department of Mines, Geological Survey Bulletin No. 20, The Catamaran and Strathblane Coal Fields and Coal and Limestone at Ida Bay, with Maps and Sections. Hobart, 1915. (From the Department.)

Tasmania Secretary for Mines, Report, 1914. Tasmania, 1915. (From the Secretary.)

U. S. Coast and Geodetic Survey, Serial No. 9, Application of the Theory of Least Squares to the Adjustment of Triangulation. Washington, 1915. (From the Survey.)

U. S. Geological Survey, The Mesozoic and Cenozoic Echinodermata of the United States. Washington, 1915. (From the Survey.)

Vereeniging Koloniaal Instituut, Vierde Jaarverslag, 1914. Amsterdam, no date. (From the Institute.)

Vetoes by the Governor of Bills and Resolutions Passed by the Legislature of Pennsylvania, Session of 1915. Harrisburg, 1915. (From the State Librarian.)

Wells Brother Company Division Greenfield Tap and Die Corporation, Catalogue No. 34 of Screw Cutting Tools and Machinery. Greenfield, Mass., no date. (From the Company.)

Western Australia Department of Mines, Report, 1914. Perth, 1915. (From the Department.)

Western Australia Statistical Register, 1913 and Previous Years. Perth, 1915. (From the Statistician.)

Western Reserve University, Bulletin, vol. xviii, No. 5. Cleveland, 1915. (From the University.)

Weston Electrical Instrument Company, Experimental Electrical Testing. Newark, 1914. (From the Company.)

Wisconsin Geological and Natural History Survey, The Peat Resources of Wisconsin. Madison, 1915. (From the Superintendent of Public Property.)

Wright Wire Company, Catalogue of Wire Rope and Wire Specialties. Worcester, 1912. (From the Company.)

PUBLICATIONS RECEIVED.

The Elements of Mechanics of Materials: A Text for Students in Engineering Courses, by C. E. Houghton, A.B., M.M.E., Associate Professor of Mechanical Engineering, New York University. Edition 2, revised and enlarged. 216 pages, illustrations, 8vo. New York, D. Van Nostrand Company, 1915. Price, $2 net.

Chemical Constitution and Physiological Action, by Prof. Dr. Leopold Spiegel (Berlin). Translated, with additions from the German, by C. Luedeking (Ph.D., Leipzig) and A. C. Boylston (A.M., Harvard). 155 pages, 12mo. New York, D. Van Nostrand Company, 1915. Price, $1.25.

Examples in Alternating Currents, vol. 1, for Electrical Engineers, by F. E. Austin, B.E., E.E., member American Association for the Advancement of Science, and of the Society for the Promotion of Engineering Education. 223 pages, illustrations, 12mo. Hanover, N. H., Author, 1915. Price, $2.40.

How to Make a Transformer for Low Pressures, second edition, with additions by Prof. F. E. Austin. 17 pages, illustrations, 12mo. Hanover, N. H., Author, 1915.

Directions for Designing, Making, and Operating High-pressure Transformers, by Prof. F. E. Austin, Professor and head of the Department of Electrical Engineering in the Thayer School of Engineering, connected with Dartmouth College, Hanover, N. H. 46 pages, illustrations, 12mo. Montpelier, Vt., Capital City Press, no date.

Mechanical Drawing for Colleges and Universities, by James D. Phillips, B.S., Professor of Drawing and Assistant Dean, College of Engineering, The University of Wisconsin, and Herbert D. Orth, B.S., Instructor in Drawing, The University of Wisconsin. 283 pages, illustrations, 8vo. Chicago, Scott, Foresman & Co., no date. Price, $1.75.

Railway Track Construction and Maintenance, by R. Bickerstaffe Holt, Highways and Permanent Way Engineer, City of Leeds. 249 pages, illustrations, 8vo. London, Tramway and Railway World Offices, no date. Price, 10s. 6d.

Canada Department of Mines, Mines Branch: Researches on Cobalt and Cobalt Alloys, Conducted at Queens University, Kingston, Ontario, for the Mines Branch of the Department of Mines. Part iii, Electro-plating with Cobalt, by Herbert T. Kalmus, B.Sc., Ph D., Assisted by C. H. Harper, B.A., and W. L. Savell, B.Sc. 69 pages, diagrams, 8vo. Ottawa, Government Printing Bureau, 1915.

Cooling Ponds for Condensing Engines, by Lee H. Parker, President, Spray Engineering Company. A paper read before the National Association of Cotton Manufactures at its 99th meeting at Hotel Griswold, New London, Conn., September 11, 1915. 25 pages, illustrations, 8vo. Boston, 1915.

Providence, R. I., City Engineer, Annual Report for the year 1914. 92 pages, tables, 8vo. Providence, City Printers, 1915.

Technical Books of 1914: A Selection. 26 pages, 12mo. Brooklyn, N. Y., Pratt Institute Free Library, 1915.

Philippine Islands, Interior Department, Bureau of Science: The Mineral Resources of the Philippine Islands for the year 1914. Issued by the Division of Mines, Bureau of Science. 41 pages, illustrations, 4to. Manila, Bureau of Printing, 1915.

U. S. Bureau of Mines: Bulletin 98, Report of the Selby Smelter Commission, by J. A. Holmes, Director of the Bureau of Mines, Chairman of the Commission; Edward C. Franklin, Professor of Organic Chemistry, Leland Stanford, Jr., University, and Ralph A. Gould, Chemical Engineer, Secretary of the Commission, in immediate charge of the investigations. With accompanying papers. 528 pages, illustrations, plates, tables, diagrams, 8vo. Washington, Government Printing Office, 1915.

Bacteriological Methods in Food and Drug Laboratories, with an introduction to micro-analytical methods, by Albert Schneider, M.D., Ph.D. (Columbia University), Professor of Pharmacognosy and Bacteriology in the College of Pharmacy of the University of California, San Francisco. 288 pages, illustrations, 12mo. Philadelphia, P. Blakiston's Son and Co., no date. Price, $2.50.

CURRENT TOPICS.

Phonograph Styluses. J. B. TAYLOR. (*Scientific American,* vol. cxiii, No. 20, November 13, 1915.)—Many of the well-known disk records, a type which has supplanted the cylindrical form except for specialized uses, have a groove of uniform depth in which a needle or stylus of steel or other metal, or sometimes of fibrous material, rests. Here the sound record is traced by a lateral motion of the stylus in the plane of the disk. There are a large number of forms, types, and makes of needles on the market, and extravagant claims are made for many of them.

To secure a faithful transmission of the sound record to the diaphragm, it is essential that there shall be no lost motion in the cam-action between the needle point and the groove. For proper tone rendering, the stylus or needle must fit and fill the slot exactly: if too small, it will be thrown from side to side, giving false tones; if too big, it will give trouble by jamming and causing excessive wear of the record. The impracticability of making records and large numbers of jewels with grooves and points of duplicate and exact curvature and dimensions is practically met by using needles of steel or other material sufficiently soft to wear from an approximate to an exact fit in the first few revolutions of playing a piece, and yet sufficiently hard to play the whole of one or two records without wearing down to too extensive a shoulder bearing or too long a base bearing for satisfactory tone rendering. For best results it is obvious that steel needles should be used to play but one record and then be discarded.

"Permanent" or multiplying needles in general, for lateral cut records, should be regarded with suspicion and used with great caution, for, while there are types of needles which may not damage a record when used intelligently, the harder a needle and the less the wear, the greater the damage to the record if the needle is removed from the holder and replaced in a different position.

Possible Source of Potash. ANON. (*United States Geological Survey Press Bulletin,* No. 245, November, 1915.)—Following Secretary Lane's instructions to put special effort into its potash investigations, the United States Geological Survey is publishing the suggestion that a possible source of potash may exist in the tailings piled up at the concentrating mills of the big copper mines in the West. The "porphyry" ores which are being mined by the millions of tons annually contain several times as much potash as copper, and this remains in the tailings at the mills, material already finely ground and in condition for treatment, as well as easily accessible for shipment. This potash, however, is locked up in the form of silicate minerals, and the commercial extraction of potash from silicates has been for several years the subject of earnest study by industrial chemists. If this problem can be solved, it would appear that a large tonnage of potash-bearing material is available in the Western States.

The brief report issued recently by the Geological Survey (Bulletin 620–J) contains typical analyses of these "porphyry" ores from the largest copper camps in a half-dozen States, as well as tonnage estimates of the ore reserves and ore already mined and treated. A few check analyses of tailings are also published.

Suggestion of a possible potash reserve in these tailings originated with B. S. Butler, the geologist in charge of the Survey statistical study of copper, who has based this short paper upon the published analyses of specimens collected by the government geologists in their investigations of the mining districts.

The significant fact regarding this possible source of potash is that in quantity it is more than adequate to meet all the needs of the country as measured by present consumption of potash. The problem of potash extraction from this by-product of the copper industry therefore becomes an attractive one for the chemical engineer and mineral technologist.

Evaporation of Potash Brines. ANON. (*United States Geological Survey Press Bulletin,* No. 244, November, 1915.)—In connection with the general potash investigations that have been carried on for several years by the United States Geological Survey, a number of desert basins in the West have been more or less thoroughly explored and many brines, saline residues, and muds have been analyzed with special reference to their content of potash. These investigations show that a few American brines contain rather high percentages of potassium, and that most brines contain it in appreciable quantity, although salts of sodium preponderate in all the brines examined. Economical methods for extracting the potash from American brines are now eagerly sought, but the work is still in the experimental stage. Fractional evaporation—a process by which brines are evaporated in stages and the deposited salts removed from time to time—is an essential part of what appears to be the most practical methods proposed, and detailed knowledge of the effects of evaporation on potash brines is therefore of paramount importance. Some experimental work to determine these effects has been done by W. B. Hicks, of the United States Geological Survey. Several different potash brines were subjected to fractional evaporation and the effect on the concentration of their constituents was determined by analysis. The results are published in a recent Survey publication—"Evaporation of Potash Brines"—issued as Professional Paper 95–E. This report shows that, in general, by evaporating the brines investigated the concentration of the potassium is increased until the solution contains about 4 per cent. of potassium, and that on further evaporation the potassium salts are rapidly deposited from solution along with larger quantities of sodium salts. The paper is a preliminary report, and the data presented suggest the importance of a more extended investigation of American natural brines.

How the Efficiency Engineer Studies the Human Machine. ANON. (*Scientific American,* vol. cxiii, No. 19, November 6, 1915.)—A valuable application of the cinematograph has been found in its use for motion study. Mr. Frank B. Gilbreth, whose work in this field is well known, has substituted the moving-picture method of recording the motions made by the operative for the tedious pad, pencil, and stop-watch method previously employed. By using a clock and a microchronometer recording the thousandth part of a second and photographing them with the operations, the exact time and duration of the motions can be recorded. Having a perfect record of the path of motion and the time, a measure of the distance is obtained by performing the operations in a cross-sectioned table and before a cross-sectioned screen. A further improvement in this method has been effected by attaching a small electric lamp to the hand of the operation so that when the photograph is taken, the path of the hand will show as a line of light. When the motions of both hands are to be distinguished, interrupters are used in the lamp circuits producing different types of dotted lines that can be readily identified.

One of the chief drawbacks lies in the cost of the films, and it occurred to Mr. Gilbreth that it was not necessary to take photographs of the size commonly used for projection on a large screen. Accordingly he devised a type of shutter which can be placed directly before the film, so that only a portion of it will be exposed. By successively so exposing several portions of the film, it was found that four pictures can be taken in the space of one. The number of exposures has since been increased to eight, then sixteen, and finally to twenty-four, so that a single reel can do the service previously required by two dozen.

Olive Oil Manufacture in Palestine. O. A. GLAZEBROOK. (*United States Commerce Reports,* No. 272, November 19, 1915.)—All olive oil made in the Jerusalem consular district, whether by the older processes or by more modern machinery, is considered as edible without refining, with the sole exception of that last pressed from the bruised berries. This, being dark and containing much of the pulp, is fit only for the soap industry, and then only after being mixed with better qualities.

The old native oil presses consist of a circular stone trough elevated a little from the ground, in which a stone disk rotates around an upright shaft. This disk turns on its edge like a wheel, and is operated by a horse, mule, or camel. One man is constantly stirring, removing, and replacing the olives as they are crushed, another man carrying the whole olives to the mill and returning with the crushed ones. Once sufficiently crushed, they are placed where they can be filled into circular baskets that have a small opening and are quite flat. These baskets have been in use for a long time.

The older extraction method, and one still much in use, calls for a wooden box for a mould, in which a large piece of coarse goat's-hair cloth is laid. The box is filled with the crushed berries, pressed compactly together, after which the cloth is folded over the top in a cater-cornered style. These are now ready for the press. This method of crushing the olives is the oldest known, possibly dating back hundreds of years, as ruins of mills would seem to indicate.

Modern mills using imported machinery, when without power, employ exactly such a crusher; when driven by a motor, as many now are, two smaller stone disks are used, both placed on the same axle. In all cases these stones are from the local native quarries.

With the primitive oil presses, there is built in one of the walls of the room a recess just large enough to admit the baskets of crushed berries and reaching to the ceiling, with a small cistern below to receive the oil. In the centre of the room is a mammoth wooden screw. A large beam extending across the room has one end entering the recess above mentioned, while in its centre lengthwise is a screw in which the larger one operates.

Once the olives are crushed and filled into baskets or hair-cloth, they are placed one upon another in the press recess, the screw is turned around and around by means of a stick of wood run through a hole for the purpose, and the gigantic beam descends, reducing the pile of baskets to half the height, while the oil runs in streams into the reservoir below. This press, being of insufficient strength, does not at once extract all the oil, so the pressed pulp is subjected to a second crushing and squeezing and then packed away in a corner of the room until the olive season is over. It is then ground for the third time and re-pressed.

These primitive devices, while they still exist, are rapidly falling into disuse, as they are too laborious and do not produce as much oil as the more modern ones.

The modern iron oil presses are either imported from France or are copies made by local machine shops. Those used where no power exists have the pressing screw operated by a long, large beam pulled by rope and tackle, while the newer types have presses operated by kerosene engines. With these metal presses but one squeezing is the rule, after which the pulp is subjected to a second crushing and pressing only for the dark soap oil. During the pressing process boiling water is poured on the pulp to make the oil separate more easily.

Since the natives are not at all particular about cleaning their mills, especially with the old type of press, the rancid oil from the previous year soon impregnates the new. Besides this, the natives commonly collect their entire crop before beginning to press, piling the berries on the flat stone roofs of their houses. The olives thus lie in a heap, often for weeks, being left until the first winter rains descend upon them—all of which is thought to help ripen the olives and thereby to produce more oil. It possibly may do so with the primitive methods, but this heating of the fruit results in a sharp and rancid product, which taste, however, the natives do not seem to mind.

A few modern mills endeavor to produce a better table oil, which they sell at an advanced price. In these the berries are not allowed to heat, and are pressed soon after being picked. The oil is stored in metal tanks, which are scoured before using, as is all the machinery employed, very sweet and clear oil being thus obtained. Some even collect the oil that of itself flows away from the crushed berries before being pressed, which is considered very superior. No methods of filtering or refining are known. The oil is simply allowed to settle and cure itself; and, while it has a sharp taste when quite fresh, this taste is soon lost.

There was $3200 worth of olive oil shipped from this district to the United States in 1914, the invoices being certified at the Jaffa consular agency.

A Gaseous-conductor Lamp for Color Matching. D. McF. Moore. (*Electrical World,* vol. 66, No. 21, November 20, 1915.)—At a joint meeting of the American Electrochemical Society and the Illuminating Engineering Society held at New York on November 11, Mr. Moore demonstrated his new carbon-dioxide vacuum tube lamp, which employs a new principle for automatically replenishing the supply of gas within the tube as the gas is used up in the operation of the lamp. Elaborate spectrophotometric investigations have been made to show that articles of various colors when viewed solely by the light of the new tube lamp have exactly the same shades of color which they display when viewed by the light from a clear sky.

The straight tube lamp is contained in an elongated sheet metal case which is provided with a screw base similar to that used on the larger sizes of incandescent lamps. Instead of feeding the lamp the CO_2 gas by means of an auto-magnetic feed valve, the gas is automatically generated within the tube itself. Near each electrode is placed a small bulb containing calcium carbonate, from which emanates the carbon dioxide when the resistance wires imbedded in it, connected in shunt to the gas column, become heated to the requisite degree. The gas column measures 7/8 inch in diameter and 1 foot in length, and appears as a solid bar of light of intense whiteness. The foot-candles available near the tube are more than 200, making the apparatus suitable for the very closest color discriminations. The degree of vacuum is automatically held within 0.001

mm. of mercury, and the apparatus will withstand wide line-voltage fluctuations without becoming disarranged in any way.

A Novel Device for Preventing the Washing of Roads. H. G. SHIRLEY. (*Maryland State Roads Commission.*)—A novel and practical device is used in the State of Maryland to prevent the washing-out of road shoulders and gutters. These "breakers," as they are termed, answer their purpose so well that they will pay for themselves after two or three heavy storms. They are considerably cheaper than cobblestone gutters, give thorough protection to the shoulders of the road, and may be used on any type of highway, including farm lanes and driveways.

The breaker consists of a low concrete barrier extending from the edge of the road diagonally through the shoulder to the ditch. It is built flush with the surface of the road shoulder, and where the highways are patrolled and the shoulders kept in repair it is no objection to travel. Breakers are spaced as occasion may require, and are neither expensive nor difficult to build. The Maryland breakers are 12 inches wide and 18 inches deep. The spacing varies with the nature of the soil, grade, and amount of water they encounter. Thus it would probably be necessary to space them closer at the bottom of a hill than at the top. On 5 or 6 per cent. grades and medium soil they are spaced 25 to 30 feet apart. Where the soil is liable to wash and the grade is steeper they would be spaced much closer. The length as well as the grade of a hill would also influence spacing.

State Production of Quinine in Italy. W. F. KELLEY. (*United States Commerce Reports,* No. 271, November 18, 1915.)—For several years past the Italian Government has operated laboratories for the production of quinine for medicinal purposes, especially for use against malaria and other fevers. The Director General of the "Regie" has recently published a report upon the State quinine production during the fiscal year ended June 30, 1914, and it is from this report that the following data are taken:

The total receipts from this industry in the year under review were $611,283, and expenditures, $451,304, showing a net profit of $159,979, a sum considerably less than that realized during the preceding year, chiefly owing to the increased cost of the raw materials. The whole of this profit was devoted to scientific investigation, drainage of unhealthful districts, free distribution of quinine, and other preventive and curative measures against malaria.

The total sales of prepared quinine in the fiscal year 1913–14 amounted to 80,782 pounds, an increase of 1891 pounds over the preceding year. A smaller demand from Greece and Bulgaria caused a falling off in total exports.

The average consumption in all Italy per 1000 inhabitants was 10,077 grains in the year under review, an increase of 1296 grains. The province of Foggia, in southeastern Italy, showed the largest consumption (44,198 grains per 1000 population), and the province of Carrara the smallest (77 grains per 1000). In the province of Rome the consumption was 22,547 grains; in Milan, 6960 grains; Turin, 6019 grains; and Naples, 3349 grains per 1000 population.

The largest quinine laboratories are at Turin, but the rapid growth of the demand for this product has necessitated the establishment of laboratories in Rome and other parts of the kingdom as well.

Electric Propulsion for a Battleship. W. L. R. EMMET. (*Proceedings of the Society of Naval Architects and Marine Engineers,* November 18 and 19, 1915.)—The Navy Department of the United States has awarded to the General Electric Company of Schenectady, N. Y., a contract for the electric propelling machinery for the new battleship *California,* which is being built at the New York Navy Yard. This ship is of the largest and most powerful class which has been adopted by the United States. Her displacement is 32,000 tons and her maximum speed is to be about 22 knots, requiring about 37,000 shaft horse-power. The contract covers two turbine-driven generating units, four propelling motors (one on each shaft), switching apparatus, cables, instruments, etc., and two turbine-driven exciting units, and a complete equipment of condensing auxiliaries and ventilating blowers, all driven by motors from the exciting units. In fact, it covers practically the entire engine-room equipment except the main condensers.

Each of the auxiliary units is of 300 kilowatts capacity, with a 240-volt direct-current generator geared to a high-speed non-condensing turbine. These turbines will exhaust into the heaters, into the main turbines, or both.

The motors which drive the auxiliaries will be designed for a considerable range of speed variation, so that the auxiliaries will be adopted to economical conditions at different speeds of the ship.

The award of this contract was the result of a very long campaign of education which has been conducted by the writer in which the equipment of the collier *Jupiter* has been an incident. The writer has from the first maintained that the proper field for electric propulsion was in ships of high power and in ships when economy at widely-varying speeds was important. The *Jupiter* has now been in commission for two years and has proved an unqualified success. The steam consumption of the main drive with 190 pounds pressure, dry steam, and 28.5 inches vacuum is 11 pounds per horse-power hour delivered to the propeller shafts, which is at least 30 per cent. better than is done by reciprocating engines in ships of the class. There is also evidence of further saving in the *Jupiter,* incident of the fact that her large low-speed propellers are turned with a perfectly uniform angular motion and with entire freedom from racing, conditions heretofore unknown with such propellers.

The generators of the *California* are bipolar alternators, and the motors are arranged to be connected either for 24 poles or 36 poles. For economic cruising at 15 knots or less, one generator will be used with motors on 36-pole connection; for higher speeds the 24-pole connection will be used. The ship will be capable of operating at a speed of 18.5 knots with one generator. Speed variation with each motor connection will be effected by change of turbine speeds through the agency of variable speed governors designed to hold automatically any desired speed within the usual ranges. This arrangement, which is also in the *Jupiter,* entirely prevents racing and makes it convenient to hold a fixed speed, irrespective of variation in sea, weather, or steam conditions. It is thought that this feature will be valuable in fleet formations.

The steam consumption guaranteed on the *California* covers the total steam required for the main turbines and the engine-room auxiliaries as described above. The conditions are 250 pounds gauge pressure, dry steam, with such vacuum as can be produced under trial conditions. The guaranteed water rates per horse-power delivered to the propeller shafts are: at 10 knots, 14.6 pounds; at 15 knots, 11.4 pounds; at 19 knots, 11.1 pounds, and at maximum speed, 11.9 pounds—a gain in propeller efficiency of 9 per cent. over other vessels of the same class equipped with the usual arrangement of turbine engines.

Better Bread by Means of Natural Lactic Acid. A. WAHL. (*The Journal of Industrial and Engineering Chemistry,* vol. vii, No. 9, September, 1915.)—(1) The general appearance of a loaf of bread is greatly improved by the use of bacterial lactic acid; a larger loaf results per weight of bread, with improved bloom and color of crust. (2) Through the chemical influences of the bacterial acidity there results a greater whiteness of crumb, with improved texture, consisting of a more uniform distribution of the fermentation gas cells, which are in smaller size in augmented number. (3) A finer flavor and increased palatableness are imparted by a chemical combination with the phosphates of the flour. (4) By using bacterial lactic acid produced by propagating *Bacillus Delbruecki* in a bran mash, all the highly nutratitious extractive substances of the bran are thus incorporated into the dough, while the lactic acid renders soluble the proteins and basic phosphates of the flour, which results in a more wholesome product by reason of its increased digestibility. (5) Undesirable microörganisms are checked. (6) Peptase and diastase are released, effecting a partial digestion of the dough, the resulting soluble proteins, phosphates, and carbohydrates serving as a most desirable nourishment for the yeast. (7) Milk, whey, buttermilk, and similar milk products containing either added or developed bacterial lactic acid, when added to the dough, also effect a similar improvement in the bread. (7) Commercial lactic acid may be used with improved results, but bacterial acid is preferable, and that bacterial lactic acid which is produced by the organism *Bacillus Delbruecki* is the most desirable, since this lactic acid, with the extractive substances in it, contains a much greater concentration of hydrogen ions upon which the effectiveness of this acid largely depends.

Safeguarding Roads in Winter. ANON. (*Office of Information, United States Department of Agriculture,* October, 1915.)—Water, not cold, is the cause of the deterioration of roads in winter, according to the road specialists of the United States Department of Agriculture. Cold weather does not in itself injure roads, no matter whether they are earth, gravel, or macadam. In fact, an earth road will bear more traffic when it is solidly frozen than at any other time. Excess water, however, is always detrimental to a highway. When cold weather turns this water into ice, the damage that it does is greatly increased.

The action which takes place when a wet road freezes to any considerable depth is similar to that which occurs when water is frozen in a closed vessel. It simply bursts or, as it is generally termed in road parlance, the road heaves. Later, when the frost leaves, the road is disintegrated and ruts badly. If this process is repeated a number of times during the winter, a gravel or macadam road may be practically destroyed, while an earth road may become entirely impassable.

The remedy is obvious: the road should be kept free of water. The time to begin preventive measures is early in the fall, before the rains begin. If the road goes into the winter thoroughly dry, with the surface and drainage in good condition, the chances are extremely favorable that it will be found intact the following spring.

The Use of Ammonium Hydroxide for the Extraction of Rosin from Wood. H. K. BENSON and H. N. CRITES. (*The Journal of Industrial and Engineering Chemistry,* vol. 7, No. 11, November, 1915).—The extraction of rosin from "light wood" in the Southern States is accomplished by first steaming the chips, next covering them with a petroleum distillate, reheating until the distillate begins to vaporize, and then withdrawing the solution of rosin. By subjecting this solution to re-distillation the solvent is recovered first, and finally the turpentine and pine oil, leaving the rosin as residue. The main difficulty with this method is the loss of the solvent in the cycle, which, according to operators, is as high as 50 gallons per cord of wood treated. Recently the use of alkalies, such as caustic soda or soda ash, has been sugggested for the extraction of rosin. The difficulty of this method lies in the form in which the rosin is finally recovered, *i.e.,* as soap, for which apparently no great demand exists as obtained from wood by this process. The present investigation is based upon (1) the instability of ammonium salts when heated and (2) the completeness of the recovery of ammonia as commercially carried on in the coal-gas plants in this country.

Powdered rosin was added to a 25 per cent. solution of warm ammonium hydroxide, forming a thick, light yellow, transparent solution which became quite firm on cooling. It slowly decomposed while standing in the air, and on adding heat the ammonium was driven off, leaving rosin as a residue. The experiments indicate that when wood is treated with a 5 per cent. solution of ammonium hydroxide, equal to eight times the weight of the wood, at 70° C. for five hours, nearly complete extraction of the rosin occurs, and from the general properties of ammonia and its complete recovery in gas works nearly complete extraction of rosin from wood may be made and the ammonia completely recovered.

A New Peat-Distillation Process. C. A. HOLDER. (*United States Commerce Reports,* No. 272, November 19, 1915.)—A new process of distillation of peat has recently been patented in Great Britain and other countries by which coke, fuel oil, toluol, ammonia, paraffin wax, and acetone are obtained in sufficient quantities and of such high grade as to prove of great value. The process has been in practical operation now some six months and seems to promise to revolutionize the peat industry and to furnish sources of fuel oil to the British Navy which may possibly make it independent of foreign oils.

Peat, as taken from the peat beds, contains from 80 to 90 per cent. of water, and is of a fibrous cellular structure, so that by hydraulic pressure it is possible to lower the water content only slightly. An important part of the new process is a macerator that breaks up the fibrous cellular tissue and thus allows a more complete separation of the water. After passing through the macerator the broken peat is compressed into briquettes, which are dried until they contain not more than 25 per cent. of moisture, and then fed into a hopper, from which they pass into the retort.

The retort, though very simple, is the basis of the patent. It contains several chambers where different degrees of heat are applied. In the first a temperature of 300° C. (572° F.) is used for driving out the moisture remaining in the peat. In the next chamber the temperature is about 450° C. (842° F.), and here decomposition of the peat takes place. In the last chambers the temperature runs up to 600 or 800° C. (1112 to 1472° F.), and the oil and water are volatilized. By means of a worm screw, briquetted peat is passed in at one end of the retort and peat charcoal is discharged continuously at the other end, while from the various chambers the oil, water, ammonia, etc., are drawn off in the form of vapor and removed from longer contact with the heat.

After leaving the chambers the vapors pass through a condensing system which is so arranged that the heavy oil collects at one place, and the water and light oil in the form of vapor, together with some combustible gases, collect in another place. The combustible gases are separated from the water and oil and are utilized in keeping up the temperature of the retort, after it has obtained its initial heat from coal, and they are ordinarily sufficient to carry on the subsequent processes without the addition of any further coal.

The coke obtained by this process contains 92 per cent. carbon, 1 per cent. moisture, 1.3 per cent. volatile matter, and 5.7 per cent. ash, and is very hard. It can be left with a larger percentage of moisture, and in this way, since it is softer, it can be used as fuel for domestic purposes. Its chief value, however, is in the manufacture of steel, owing to its wonderful hardness and the high percentage of carbon contained. Various steel makers have certified to its great value for this purpose. From a ton of peat nearly one-third of a ton of coke, valued at $6.08 to $7.30, is obtained.

The oil promises to be particularly useful as a fuel because of its low sulphur content. An examination of the oil showed it to be a most satisfactory substitute for petroleum. The amount of ammonia obtained per ton of peat is estimated at 20 pounds, with a value of two cents or more per pound. Both the oil and the ammonia contain water, but this is readily removed by the application of heat. In addition to these products, about 20 pounds of paraffin wax, valued at six or eight cents per pound, is obtained, and toluol and acetone; the quantity and value of the latter have not yet been ascertained. The paraffin wax is of good quality and can be employed for candle making and other purposes.

With peat costing about $1.95 per ton delivered in the hopper, dry, it is believed that by this process a profit of not less than $3.65 or $4.87 per ton will be obtained; and this does not include any allowance for the toluol and acetone, which may prove to be more valuable than all the other products together.

Peat from different localities gives different results, some peat containing larger amounts of volatile matter than others, and some peat having a low nitrogen content, while in others it is high. The yield of oil from English peat (Yorkshire) was 26.5 gallons per ton. By varying the conditions of distillation light or heavy oils may be produced as desired. The yield of oil, gas and ammonium sulphate can be controlled by regulating the length of time or the degree of heat to which the peat is subjected in the retort.

Of the many attempts that have been made to utilize peat this method is said by many experts to promise most.

INDEX TO VOL. CLXXX.

Aëronautics, Recent progress in (Reber), 437
Animals, Production of light by (Dahlgren), 513, 711
Alternating current, On an unbroken, for cable telegraphy (Squier), 311
Arny, H. V., and C. H. Ring: Standardized colored fluids, 199

Bartholomew, W. S.: Mechanical stoking of locomotives, 253
Batho, Cyril: The effect of the end connections on the distribution of stress in certain tension members, 129
Bazzoni, Charles Blizard: Loss of weight of musk in a current of dry air, 463.
Bazzoni, Charles Blizard, and Joseph Samuel Hepburn: On the retention of activity by urease and by oxidase after exposure to the temperature of liquid air, 603
Biochemical and engineering aspects of sanitary water supply (Fuller), 17
Boiling-point of aqueous solutions of nitric acid (Creighton and Smith), 703
Book Notices:
  Dall, William Healey: Spencer Fullerton Baird, A Biography, 121
  Leffmann, Henry: Analysis of milk and milk products, 378
  Marshall, Arthur: Explosives, 120
  Murdoch, W. H. F.: Electrical instruments in theory and practice, 378
  Phillips, Francis C.: Chemical German (second edition), 501
  Sadtler, Samuel Schmucker: Chemistry of familiar things, 500
  U. S. Bureau of Mines Bulletin 94, United States Mining Statutes Annotated, 631
  Vulté, Hermann T.: Household Chemistry, 379
  Williams, Herbert E.: The chemistry of the cyanogen compounds, 119
  Willows, E. S., and E. Hatschek: Surface tension and surface energy, 630
  Ziegel, Henry: Brief course in metallurgical analysis, 501
Bradbury, Robert H.: Recent tendencies in high-school chemistry, 449
Brooks, Benjamin T.: The cracking and distillation of petroleum under pressure, 653

Cable telegraphy, On an unbroken alternating current for (Squier), 311
Cameron, Frank K.: Possible sources of potash in America, 641
Chemistry, high-school, Recent tendencies in (Bradbury), 449
Coblentz, W. W.: The physical photometer in theory and practice, 335
Color-mixture equations, transformation from one system to another (Ives), 673
Color standards: standardized colored fluids (Arny and Ring), 199
Control and protection of electric systems (Steinmetz), 1
Correspondence:
  A relation concerning the distribution of an electrolyte between water and some second solvent and its dissociation constant in aqueous solution (Creighton), 741
Cracking and distillation of petroleum under pressure (Brooks), 653
Creighton; Henry J. M.: A relation concerning the distribution of an electrolyte between water and some second solvent and its dissociation constant in aqueous solution, 63, 741
Creighton, Henry Jermain Maude, and Herschel Gaston Smith: On the boiling-point of aqueous solutions of nitric acid at different pressures (Part II), 703
Current Topics, 16, 62, 99, 100, 122, 123, 213, 214, 223, 224, 240, 246, 247, 334, 368, 376, 380, 381, 448, 461, 462, 470, 476, 479, 480, 487, 488, 493, 494, 502, 503, 537, 538, 560, 566, 601, 602, 606, 621, 622, 623, 633, 652, 701, 702, 709, 710, 728, 733, 734, 748

DAHLGREN, ULRIC: Production of light by animals, 513, 711
DAVIS, CARLETON E.: Early municipal water works at Panama, 561

Eastman Kodak Company, Research Laboratory Notes, 481
Electric systems, Control and protection of (Steinmetz), 1
Electricity, Recent researches in, at the Bureau of Standards (Rosa), 539
Electrification, Conditions affecting the success of main-line (Murray discussion), 75
Electrolyte, Relation concerning the distribution of an, between water and some second solvent (Creighton), 63, 741

Factor to be used for the calculation of the phosphoric acid in Neumann's Method. The factor as influenced by the water used for washing the yellow precipitate (Jodidi and Kellogg), 349
FRANKLIN INSTITUTE:
  Board of Managers, Minute on the death of John T. Morris, 625
  Board of Managers, Resolutions on death of John Birkinbine, 241
  Franklin Medal, award of, 107
  Library notes, 116, 242, 377, 496, 630, 743
  Membership notes, 114, 242, 495, 626, 742
  Science and Arts Committee, Proceedings: June 2, 1915, 114; September 1, 1915, 495; October 6, 1915, 624; November 3, 1915, 739
  Science and Arts Committee, Resolutions on the death of Richard Gilpin, 241
  Sections, proceedings of meetings: 624, 740
  Stated meeting, proceedings: October 20, 1915, 623; November 17, 1915, 739
FULLER, GEORGE W.: Biochemical and engineering aspects of sanitary water supply, 17

General Electric Company, Research Laboratory Notes, 489

HEPBURN, JOSEPH SAMUEL, and CHARLES BLIZARD BAZZONI: On the retention of activity by urease and by oxidase after exposure to the temperature of liquid air, 603

IVES, HERBERT E.: The establishment of photometry on a physical basis, 409
IVES, HERBERT E.: The transformation of color-mixture equations from one system to another, 673

JODIDI, S. L., and E. H. KELLOGG: On the factor to be used for the calculation of the phosphoric acid in Neumann's method. The factor as influenced by the water used for washing the yellow precipitate, 349

KELLOGG, E. H., and S. L. JODIDI: On the factor to be used for the calculation of the phosphoric acid in Neumann's method. The factor as influenced by the water used for washing the yellow precipitate, 349
KINGSBURY, E. F.: A flicker photometer attachment for the Lummer-Brodhun contrast photometer, 215

LEVY, LOUIS EDWARD: Development and recent advances of the technographic arts, 387

Light, Production of, by animals (Dahlgren), 513, 711
Locomotives, Mechanical stoking of (Bartholomew), 253

Magnetism, Modern theories of (Stradling), 173
Mechanical stoking of locomotives (Bartholomew), 253
Military aëronautics, Recent progress in (Reber), 437
MURRAY, W. S.: Conditions affecting the success of main-line electrification (discussion), 75
Musk, Loss of weight of (Bazzoni), 463

Nela Research Laboratory Notes, 235, 477, 617, 735
Nitric acid, On the boiling-point of aqueous solutions of (Creighton and Smith), 703

Oxidase, Retention of activity of, after exposure to the temperature of liquid air (Hepburn and Bazzoni), 603

Panama, Early municipal water works at (Davis), 561

Petroleum, The cracking and distillation of, under pressure (Brooks), 653
Phosphoric acid in Neumann's method, On the factor to be used for the calculation of the. The factor as influenced by the water used for washing the yellow precipitate, 349
Photometer, A flicker photometer attachment for the Lummer-Brodhun contrast photometer (Kingsbury), 215
Photometer, Physical, in theory and practice (Coblentz), 335
Photometry, Establishment of, on a physical basis (Ives), 409
Potash, Possible sources of, in America (Cameron), 641
Publications received, 121, 246, 379, 502, 631, 746

Railroads, electrification, Conditions affecting the success of main-line (Murray), 75
Reber, Samuel: Recent progress in military aëronautics, 437
Relation concerning the distribution of an electrolyte between water and some second solvent and its dissociation constant in aqueous solution (Creighton), 63, 741
Ring, C. H., and H. V. Arny: Standardized colored fluids, 199
Rosa, E. B.: Recent researches in electricity at the Bureau of Standards, 539

Smith, Herschel Gaston, and Henry Jermain Maude Creighton: On the boiling-point of aqueous solutions of nitric acid at different pressures (Part II), 703
Squier, George O.: On an unbroken alternating current for cable telegraphy, 311
Standardized colored fluids (Arny and Ring), 199
Steinmetz, Charles P.: Control and protection of electric systems, 1
Stoking of locomotives (Bartholomew), 253
Stradling, George Flowers: Modern theories of magnetism, 173
Stresses. Effect of the end connections on the distribution of stress in certain tension members (Batho), 129

Technographic arts, Development and recent advances of the (Levy), 387
Telegraphy, cable, On an unbroken alternating current for (Squier), 311
Tension members, Effect of the end connections on the distribution of stress in certain (Batho), 129
Theories of magnetism, Modern (Stradling), 173
Transformation of color-mixture equations from one system to another (Ives), 673

U. S. Bureau of Standards, Notes, 101, 225, 369, 471, 607, 729
U. S. Bureau of Standards, Recent researches in electricity at the (Rosa), 539
Urease and oxidase, Retention of activity of, after exposure to the temperature of liquid air (Hepburn and Bazzoni), 603

Water supply, Biochemical and engineering aspects of sanitary (Fuller), 17
Water works, Municipal, at Panama (Davis), 561
Weight of musk, Loss of, in a current of dry air (Bazzoni), 463

PRESS OF
J. B. LIPPINCOTT COMPANY
PHILADELPHIA

T
1
F8
v.179-
180

Franklin Institute,
Philadelphia
Journal

[redacted]

Engineering

PLEASE DO NOT REMOVE
CARDS OR SLIPS FROM THIS POCKET

UNIVERSITY OF TORONTO LIBRARY

ENGIN STORAGE